Collaborative Study on Strategies to limit CO_2 emissions in Asia and Brazil

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Prepared by

Asian Energy Institute
9 Jor Bagh,
New Delhi 110 003
INDIA

Edited by

Dr. Prodipto Ghosh

Ms. Amrita N. Achanta

Ms. Preety Bhandari

Ms. Mala Damodaran

Ms. Neha Khanna

Tata Energy Research Institute
9 Jor Bagh
New Delhi 110 003
INDIA

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CHAPTER 1 : INTRODUCTION

1.1 Scope of the study

The potential impacts of emissions of carbon dioxide (and other Greenhouse Gases-GHGs) global climate through the Greenhouse Effect have generated international debate on the possibilities of limiting these emissions, and on the global policy framework within which stabilization (or actual reduction) in these emissions may be accomplished over time. The issue of abatement of these emissions presents a serious policy dilemma to developing countries which are attempting to increase energy supplies so as to ensure rapid improvement in living standards for their populations. This dilemma has been explicitly recognized, albeit in a broader framework, by the U.N. General Assembly in convening the U.N. Conference on Environment and Development (UNCED) in Brazil in 1992.

In any global study of human societies and environmental impacts, the Asian continent and Brazil present a highly diverse range of social systems, political philosophies, and economic achievements. This group includes an industrial giant, such as Japan, a newly emerging industrial power, such as the Republic of Korea, large and populous countries like Brazil,China and India with major industrial activities, and some of the poorest countries of the world, for example Bangladesh.

According to several studies, Asia and Brazil are likely to experience the highest rates of economic growth of major world regions, well into the next century. Largely on this account, it is also believed that CO_2 emissions in Asia will increase at a faster rate than in any other region in the world. Further, it has been contended that Brazil emits the largest quantity of CO_2 attributable to deforestation. It is therefore,important not only to study the sources and activities that produce these emissions,but also evaluate potential solutions by which these could be minimized in the future in cost effective ways.

The overall aim of the present study is to identify and evaluate existing and emerging technologies to limit CO_2 emissions for different sectors of the economies of the participating countries. These technologies, which may be implemented by year 2000, may be broadly classified as follows :

1. Improvements in energy efficiency and energy conservation.
2. A shift to lower carbon fuels such as natural gas and greater use of renewable resources such as hydro, solar, wind, etc.
3. Afforestation to sequester atmospheric carbon.

The broad plan of the study for each participating country is as follows :

First the feasible technologies are identified, following which an analysis of the potential for adoption of each technology by the year 2000, the related costs and CO_2 abatement made possible over the lifetime of the technology is undertaken. A country specific approach is adopted, keeping in mind overall economic growth and other policy concerns of the country involved. The concept of "cost" vary across the different country studies, which are thus not comparable in this particular aspect.

Two points need to be emphasized in establishing the significance of this study :

First, while the countries of Asia and Brazil have not been major contributors to the increased atmospheric concentrations of GHGs in the past, their share is likely increase rapidly relative to other regions in the future. Also, certain regions of Asia would perhaps be the most vulnerable to the adverse effects of Climate Change. For example, the Maldives and other coastal areas of South Asia with respect to sea level rise; parts of Brazil, China and India with respect to impacts on agriculture; and all the major river basins and deltas of Asia with respect to changes in precipitation patterns.

Second, in any global effort to limit the emissions of GHGs and measures to reduce their concentration in the atmosphere, policy makers and leaders of public opinion can best be persuaded by analysis and research by credible institutions located in the concerned countries themselves, rather than relying on the work of scholars who may have little first-hand knowledge of conditions and policy concerns of the respective countries.

The Asian Energy Institute (AEI) is a networking arrangement of eleven well established research institutions in Asia located in the major countries of the continent, and a collaborative process of working between them is already in existence, of which the present study is an embodiment. In addition, Brazil also participated in the study. This is because it was felt that the inclusion of a populous and rapidly modernizing economy such as Brazil would add further strength to the effort, and provide a useful reference for comparison to the Asian scene, and would thus enhance the value of the research to the global community.

The report is structured as follows :

This introductory chapter addresses some general issues of common interest to all the participating countries such as notions of equity in climate change, various concepts of abatement costs, and the issue of technology transfer. Chapter 2 to 9 contain the individual country papers, in the following order : Bangladesh, Brazil, China, India, Iran, Japan, South Korea and Thailand. While some attempt has been made to maintain a common format for all the country studies, this has not been wholly achieved. However, each country paper is preceded by an executive summary of its main contents.

1.2 Structuring the Equity Issue

The key to an eventual international instrument for regulation of Climate Change is the issue of equity or fairness. Equity is involved not only in the distribution of possible benefits of control, but also, importantly, in the costs of abatement responsibilities. A gestalt view of the latter aspect is that since a Protocol would have to limit global emissions, and also apportion entitlements to emissions (or the share of net revenues that might be yielded by the use of international regulatory instruments, such as carbon taxes or tradeable permits), real resource transfers are involved in such schemes. Further, since in the multilateral context, any regulatory scheme must include norms or the basis for assigning emissions rights, or revenues yielded by policy instruments, a separation of positive and normative aspects is analytically impermissible. Again, since the sharing of burdens, entitlements, and benefits would occur not only among countries or regions, but also across human generations, equity in the context of Climate Change has both spatial and temporal dimensions. The issue is complex, and in this paper we do not attempt anything more than providing an outline of a framework for analysis of the problem.

1. The Developing Country Perspective:

Notions of equity or "fairness" are deeply intertwined with the idea of "equality." However, fairness is a primitive or intuitive notion, and cannot be further broken down analytically.

The term 'equality' is used in different senses. It may refer to "equality before the law", i.e., equality of treatment by authorities. Alternatively, it may refer to "equality of opportunity", i.e., equality of chances in an economic system. A third meaning is "equality of result", i.e., equal distribution of goods.

These three concepts can also be seen as involving different relations of the "State" to inequalities that exist, or arise in society. Equality before the law means that laws do not recognize distinctions between persons that are irrelevant to their economic activities, but that otherwise policies do not attempt to eliminate inequalities as they arise. Equality of opportunity means that the State intervenes to ensure that inequalities do not cross generations. Equality of result implies that the State periodically or continuously intervenes to ensure that inequalities arising from activities are not accumulated.

In applying these concepts to Climate Change, the first key question is that of the "identification of agents", i.e., between whom is it meaningful to speak of equity. Ordinary notions of equity involve fairness among human individuals as agents, although often phrased in terms of equity between different groups, or classes. An intuitively appealing notion of "agent" in the Climate Change context would be human beings, irrespective of where or when they happen to live. Alternative notions of 'agent', for example, countries, regions, or defined communities are unappealing, if for no other reason than that they are susceptible to fundamental change in character and composition in the time frame of Climate Change. In that case, i.e., with agents as individuals as defined above, sovereign States may assume the role of trustees with respect to their citizens in the matter of equity in Climate Change, and an attribute of sovereignty would be that such a claim of trusteeship is not open to challenge.

What would 'equality under the law' imply, given this definition of 'agent'? Since under this principle, no note must be taken of distinctions which are irrelevant to the activities of the agents, a multilateral regulatory framework cannot distinguish between individuals on the basis of nationality, temporal generation, or other attributes, such as race, religion, or colour.

What of 'equality of opportunity'? This principle requires that inequalities (in wealth, welfare) arising from differential levels of GHGs emissions do not carry over across generations. Specifically, at a minimum this principle would seem to require that the access to GHGs emissions cannot be hereditary or based on precedent, (ruling out "Grandfathering" as a basis for emissions entitlements), and that the incremental wealth accruing to individuals from higher, unentitled GHGs emissions by them, cannot be bequeathed to their offspring. This principle furnishes the basis for the assertion that societies with higher historical per-capita emissions, should compensate societies with lower past per-capita emissions. Ensuring equality of opportunity is a central concern of the welfare State, and (to varying degrees) is sought to be realized in all but avowed legally minimalist States. Little support may be found in international public documents, or current instruments, for abrogating this principle.

Finally, 'equality of result'. Different ethical schools have evolved to address this question, albeit in the context of distribution of the national income between different social classes or groups. In the Climate Change context, this principle should be interpreted as equal per-capita rights to GHGs emissions across all agents.

Several philosophical positions take equality of result as 'natural', in the sense that while it needs no justification, deviations from the principle would require it. It is possible to derive an equal per-capita entitlements to GHGs emissions from at least the principles of Egalitarianism (Rawls), Utilitarianism (Bentham, Pigou), and Libertarianism (Nozick), which otherwise have rather different perspectives on the role of the State.

Developing countries assert that their levels of past, current, and (foreseeable) future per-capita GHGs emissions would not aggregatively induce Climate Change. On the other hand, just the past rates of emissions of industrialized States suffice to ensure increasing concentrations of GHGs in the atmosphere. Further, because of the apparent close linkages between economic growth and GHGs emissions, developing countries cannot accept any commitment with regard to their emissions levels in the foreseeable future. In addition, equity principles, as argued above, would justify compensatory transfers to them for the historically high levels of emissions by industrialized countries.

2. Developed Country (Japan's) Perspective:

The equity issue in Climate Change involves arriving at a rule or principle for equitable "burden sharing". The issue of how burdens should be shared between different countries is formidable because of the diversity in the conditions of countries, including, in particular, differences between developing countries and industrialized countries. Any particular way of normalizing CO2 emissions, for example on per-capita or per dollar of GDP reveals wide divergences among countries. It is essential to take a step-by-step approach, so that these realities can be properly accounted for.

In the context of equity between industrialized countries, one proposal under discussion is to set a target for stabilizing total CO2 emissions at the present level uniformly across countries by year 2000. While this approach is simple to comprehend, in fact it is iniquitous because it involves major differences in burden sharing. A further process of reductions in emissions by uniform percentages (over country totals or norms, for example, per-capita, which is a more equitable basis than country totals), would accentuate the inequities in burden sharing. To avoid such a situation, it will be useful to incorporate as yardsticks a combination of diverse factors, including population, income, and climate (or temperature). In a more distant time-frame, it may be necessary to adopt other criteria, such as energy utilization, efficiency by sector, by end-use, or by process.

Equity issues between developing and industrialized countries, would, however, need to be addressed on a different basis. It is clear that the problem of Climate Change cannot be solved without the participation of developing countries. However, industrialized countries wil have to be more sensitive to the desire of developin countries for increasing their standards of living, whic will involve increased energy consumption, as is the cas with industrialized countries. In addition, in the time spa of at least the next 20-30 years, any effort by developin countries to reduce GHGs emissions while maintaining economi growth, will be contingent on assistance from industrialize countries. Having said this, one may note that the current life-styles of industrialized countries do not necessaril furnish a good model for developing countries to follow i the future.

An optimal and realistic rule of equity, whether between industrialized countries, or between developing and industrialized countries, will depend on the time frame under consideration. The mechanism of equitable distribution of burdens will vary depending on the nature of the international agreement that may be formed at each phase of the time span. The issue of equity is the key, and will require consideration again and again, whether at the level of concepts, or as application to an international response strategy.

3. Synthesis

The developed and developing country perspectives presented above, represent two divergent positions on the equity question in Climate Change. It is unlikely that a determination of the equity issues will be achieved at the current INC negotiations for a Framework Convention. However, on two proposals before the INC, there is general agreement among the scholars who have participated in the current exercise. That is, first, that industrialized countries should first stabilize, and then reduce, in some agreed near time-frame, their CO2 emissions. Second, that while developing countries may adopt strategies for reducing the growth rate of CO2 emissions by them, without adversely impacting their economic prospects, these would be possible only if the full incremental costs of the strategies are met through financial transfers from industrialized countries. Further, such financial transfers would need to be complemented by a regime for technology transfers to enable the adoption of the less CO2 intensive growth paths by developing countries.

It is also recognized that if there is to be a negotiated determination of the equity question, each side would need to demonstrate flexibility. In other words, the negotiators must appreciate both the strengths of the principles enunciated by each side, as well as the practical difficulties and adjustment costs in embodying these in a regulatory framework in the near term. However, in the long-term, while the GHGs intensive economies would have to be restructured, a regime of permanent international division of labour based on differential access to GHGs emissions would be inappropriate.

1.2.2 Notions of Abatement Costs

Costs of abatement are increasingly occupying an important position in international negotiations on a Framework Convention for Climate Change. The debate on costs of abatement does not centre on whether they are important but at one level, on the manner in which they should be computed. The recently concluded World Conference on Clean Energy at Geneva (November, 1991) suggested the formulation of a Global Energy Charter for sustainable energy policies, in which cost considerations are incorporated in the following manner:

1) The establishment of guidelines and internationally standardized methodologies of calculation for determining external effects and lifecycle costs for all energy systems, taking into account environmental, health and other damages caused by energy related activities.

2) Based on these guidelines, the introduction of a system of full cost pricing coupled with a system of compensation for external damages from all energy related activities, not excluding waste disposal and decommissioning, to reflect the total societal, including environmental, costs.

3) The creation of dedicated energy funds, one to be called the Climate and Energy Fund, allocated from external cost levies and other sources, for the financing of energy efficiency improvements and best available environmentally sound energy technologies, with special arrangements for countries which would not otherwise be able to introduce such measures.

It is necessary that abatement costs are determined by the regions involved in the transactions. Several problems arise at this point since perceptions of what comprise abatement costs differ, and consequently the implications in terms of possible financial transfers also vary. The variations are primarily a function of the cost of the technology, the state of development of the region receiving the transfer, and level of indigenous technology.

We cite below a few cases to give an indication of the different perceptions of costs of abatement. When comparing two technologies, it is assumed that both yield the same level of service. Further, as a terminological matter, we assume for all cases that a change in CO_2 emissions implies a shift from technology A to technology B. In the traditional definition, marginal cost is the cost of producing one additional unit of the good. When referring to the Long Run Marginal Cost (LRMC), one is considering a plant to be set up in the future, thereby allowing for the capital investment to be a variable, in addition to all other inputs. In the calculations, the discounted values of the yearly operating and maintenance, and fuel costs are added to the initial investment, to arrive at the present value of the investment.

Case I : If incremental cost is perceived as the change in the net cost of CO_2 abatement for a given level of service, i.e., (i) CO_2 emissions from technology B for a given level of service are less than CO_2 emissions from technology A for the same level of service, and (ii) LRMC of B is less than LRMC of A, for a given level of service, then technology B then dominates technology A in terms of both reduced CO_2 emissions and discounted present value of costs. Here the abatement costs would be the negative of the change in LRMC over the change in CO_2 i.e.,

$$\text{Long run marginal abatement cost} = -\left(\frac{LRMC_B - LRMC_A}{CO_2\,B - CO_2\,A} \right)$$

This results in a ratio in terms of dollars per unit of CO_2 abated. If technology B dominates A, in this case, both the numerator as well as the denominator would be negative, thereby yielding a negative ratio and vice-versa. The ratio would then serve as an indicator of the average benefit per unit CO_2 abated. The "long run marginal abatement cost", thus provides a means for ranking candidate technologies.

Case II: Here investment costs are considered to be the basis for comparison. In this case, technology B would dominate technology A if (i) capital investment of B is less than capital investment of A and (ii) CO_2 emissions from B are less than CO_2 emissions from A. In this case the abatement costs would be defined as the negative of the ratio of change in CO_2 emission and change in capital requirements, for a given level of service i.e

$$\text{Marginal abatement investment cost} = -\left(\frac{Capital_B - Capital_A}{CO_2\,B - CO_2\,A} \right)$$

Here again the ratio would be in terms of dollars per unit CO_2 abated. In this case, the likelihood of the ratio being positive is high, since for most CO_2 benign technologies, the upfront investment costs are significantly higher than that of the conventional backstop. While this ratio too could be useful to policy makers as a means of ranking alternative technologies, because shortage of capital resources are often the main constraint to the adoption of new technologies, its limitations should be kept in mind. These arise from the absence of discounting costs over time, and the neglect of O & M, and fuel costs. The overall bias involved is likely to favour conventional backstops.

Case III: In this case, the net benefits of the two technologies are considered. Again technology B would dominate technology A if (i) the net benefits of technology B are greater than those from A and (ii) CO_2 emissions from B are less than those from A. We thus define :

$$\text{net benefit of abatement} = - \left(\frac{\text{Net Benefit}_B - \text{Net Benefit}_A}{CO_2\,B - CO_2\,A} \right)$$

In this case if the ratio is positive and the change in CO_2 emissions negative, technology B dominates technology A, and vice versa. The problem with this approach lies in the uncertainties of quantification of benefits (which should include the benefits of reduced CO_2 emissions and of other environmental benefits) over time, which may be significantly higher than the uncertainties involved in computing costs over time. In the present study, as noted earlier, the different country studies have emplo

different notions of costs of CO_2 abatement. This refle

differences in the availability of data between countri

and also perhaps, varying policy perceptions.

1.2.3 Transfer of Technology

Technology transfer is defined as the process by wh technology, knowledge and/or information developed in organization, in one area, or for one purpose is applied utilised in another organization, in another area or another purpose.

It includes all activities necessary to secure successful transfer to and adoption by the recipient coun of technologies, techniques and practices, both existing in prospect, which increase the ability of an economy to m the needs of its consumers. It also includes, the full absorption of technologies and development of indigen capacity for technological adaptation, replication innovation.

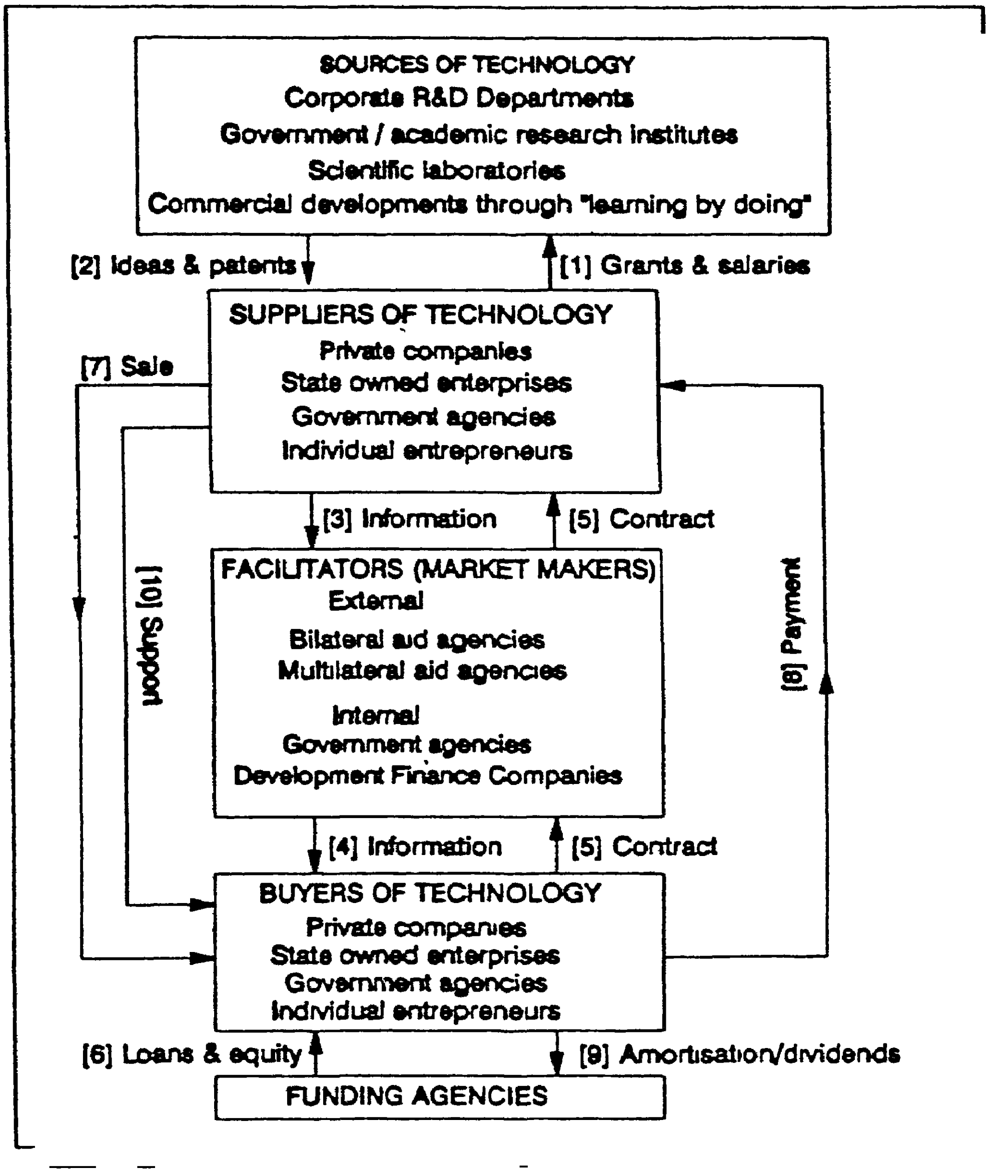
Bell (1990) distinguishes between three categories transferable technology and has identified them as th flows.

i. Flow A : Capital goods, Services and Design specifica

ii. Flow B : Skills and Know-How for Production.

iii. Flow C : Knowledge and Expertise for Generating Managing Technical Change.

Technology Transfer: Parties and Flows



Source : 'Global Climate Change - The Role of Technology Transfer, A report for the UNCED by Touche Ross Management Consultants, pp. 35, February 1991.

Flow A : Capital goods ,Services and Design Specifications : Technology here refers to hardware or machinery and equipment, which is acquired and brought into operational use during investment projects. Other technological and managerial services included in investment projects cover execution of planning and feasibility studies, types of design engineering, project management services and so on.

The flow of capital goods and services add to the technology importer's physical facilities for production, or in the case of equipment designs, provide domestic capital goods producers with specifications for production of similar facilities.

Flow B : Skills and Know-How for Production :
Included among most technology transfer agreements are the flow of know-how required to operate and maintain new or improved production facilities. The two main components in this flow are :

a. 'Paper embodied technology' in the form of manuals, schedules, flow charts including operating procedures, maintenance and repair procedures, routine quality control and possibly even procedures for marketing outputs and purchasing inputs.

b. 'People embodied technology' refers to knowledge and expertise required to carry out procedures which in turn includes training of individuals in requisite skills or in dealing with situations not covered in manuals and routines.

Although Flow A and Flow B add to the production capacity of the technology importing firm, they do not contribute substantially to the importer's 'technological capacity'. Neither transfer of capital goods nor of know-how (which aid in production of a product) add to the expertise and experience required to change, adapt and develop the product in the future.

Flow C : Knowledge and Expertise for Generating and Managing Technical Change :

Like Flow B, it also consists mainly of information and people embodied knowledge and expertise. It differs from Flow B , in that it is concerned with transferring the skills needed for changing technical systems. There is some overlap between Flow B and Flow C.

In this case, the component of knowledge and information about the production system would be greater than that required for routine operation and maintenance. The other component would be expertise needed for undertaking various engineering studies and design engineering, or evaluation of alternative plans and designs, or incorporation of technology in new or improved production systems.

Technology transfer in the context of Climate Change

Technology transfer relating to Climate Change could be within these areas;

- Establishment and improvement of monitoring systems
- Technologies to stabilize and mitigate greenhouse gases.
- Technologies to adapt to Climate Change

The Ministerial declaration at the end of the Second World Climate Conference stated that:

"Developing countries must, within the limits feasible, taking into account the problems regarding the burden of external debt and their economic circumstance, commit themselves to appropriate action.

The aim of increasing the effectiveness of technology transfer mechanism must take into consideration the needs of the developing countries, the present obstacles to such technology transfer, and the treatment of such transfer in existing and future international agreements.

To this end, there is need to meet the requirements of developing countries, that adequate and additional financial resources be mobilized, and the best available environmentally sound technologies be transferred expeditiously on a fair and most favourable basis".

The developing country perspective is that the responsibility for having increased the CO_2 concentrations and committed the earth to warming lies with the industrialized countries. Nevertheless, developing countries may have to share the responsibility of curbing future emissions, given that their energy consumption will, in course of time, be comparable to that of the industrialized countries.

The availability of the latest technology to the developing world, would aid significantly in their ability to limit GHGs emissions . The necessary technology for most part is inaccessible to the developing countries given the protection afforded by Intellectual Property Rights (IPRs).

Given these circumstances not only is it necessary that favourable financial transfer arrangements are created for transfer of technology, but information leading to the choice of the most appropriate technology by the developing country as well as its successful absorption within the recipient country are essential prerequisites.

Modes/mechanisms of technology transfer

Technology can be transferred from a supplier country to a recipient country using varying mechanisms as categorized below: The methods of technology transfer may be classified as commercial and non-commercial. Commercial transfers refer to enterprise-to-enterprise interactions. The principal commercial methods of transfer are:

(1) Private direct foreign investment in a host country subsidiary or a joint venture

(2) Licensing of IPRs

(3) Technical assistance

(4) Sale; importation, installation and servicing of machinery and equipment and other capital goods; and

(5) Franchising of consumer goods and services.

Some non-commercial methods of technology transfer are : (1) Advisory groups (2) Personnel Exchanges (3) Information Dissemination and (4) Education

It must be noted though that successful transfer mechanisms are usually a combination of several of these mechanisms. The success of the mode of technology transfer is a function of the stage of technological development, end users and other factors. For example, a technical journal article could provide technical information more effectively on a new idea early in the development process, while a workshop would be less effective at that stage of development.

Foreign Investment

Technology transfer and private direct foreign investment often occur in conjunction with each other but each can stand alone. The flow of technology to developing countries has normally constituted a part of direct foreign investment, normally done by large transnational corporations.

Transfer transactions between affiliates constitute a significant share of today's transactions. Transactions involving the parent firm and their branches, or wholly or majority owned subsidiaries are normally done informally and do not include formal agreement. In contrast , when the foreign investment is in the form of a joint venture where the local partner is a majority owner, then a formal agreement/license is negotiated between the technology supplier and the local recipient.

The mechanism of foreign investment appeals to the supplier from the viewpoint of control. This would ensure control of the local enterprise's management, operation and marketing, apart from a control of the technology itself, as a trade secret. This is favourable also in that the supplier has the opportunity to earn returns in the form of dividends, instead of technology fees or royalties. From the viewpoint of the recipient, foreign investment brings in capital in the form of foreign exchange and the security of the foreign partner's long-term commitment. On the other hand the foreign partner will be taking dividends instead of "only" royalties.

Licensing of Industrial Property Rights

Technology transfer can occur completely independently from foreign investment by means such as industrial property licenses.

A patent or trademark license gives the technology recipient permission to do certain acts covered by the exclusive rights conferred by law on the patent or trademark holder (the technology supplier). The permission is normally obtained by the payment of a lump-sum technology fees or royalties.

An agreement of such a kind enables a foreign licenser, unwilling to risk his capital in a developing country, or uncertain of a project's profitability, or unable to invest in conditions acceptable to him, to benefit in the form of fees, royalties and profits from assured sales of components and products. In those countries where foreign investment is regulated and local entrepreneurship exists, the method of technology licensing is increasingly used. This has been the experience in India, for example.

Where restrictive host country foreign investment laws are prevalent, in the form of prohibition of foreign equity participation in certain economic sectors, or legislation requiring a phased 'fade-out' of foreign ownership in local subsidiaries/joint ventures: it encourages Trans National Corporations (TNC's) interested in investing in such countries to opt for such licensing agreements in place of foreign investment. Another factor influencing the technology supplier's choice in favour of licensing as compared to foreign investment, is that the supplier penetrates the host country market, without spending or risking capital. Licensing is also convenient in that it is for a finite duration. From the recipient's point of view, licensing leaves him free of foreign control and interference. The recipient also benefit from its interaction with its own government to ensure the agreement is equitable.

Issues in contention during technology transfer

Developed vs developing countries :

Technological transfer to a developing country can be understood as most often being from an industrialized country; although some developing countries are now technology suppliers. The potential for South- South cooperation deserves greater attention, given the increasing technological capabilities of countries like Mexico, Brazil, Egypt, India and China.

An estimate of the dominance of industrialized countries as technology suppliers, is the United Nations estimate that developing countries were granted only 6% of the world stock of patents in 1970. Of these LDC patents only 1% of the world stock was owned by developing country nationals. Another noteworthy feature is that TNCs control a major share of the world's technology.

There are many instances where the best available technology has undergone transfer from the developed world to a developing country under patent protection. Nevertheless there exists a reluctance on the part of some companies of the developed world to part with the State of the Art (SOA) technology to others. This could be either due to the technology holder's reluctance to lose his competitive advantage to competing producers; or the technology could prove inherently dangerous in the absence of stringent, reliable, operating and maintenance practices on the part of the licensee.

The international technology transfer process in existence has been found to be disadvantageous from the developing country viewpoint. The objectives of absorption, adaptation, innovation and dissemination are difficult to realise in the present milieu. Some of the complaints of developing countries include :

a) Technology transferred is inappropriate or obsolete
b) Imposition of onerous terms and conditions on technology recipients in transfer agreements in the form of overpricing or restrictive business practices.
c) Intellectual Property Rights favour cartel behaviour.

Other complaints relate to cost, access, information, support and market needs.

In the same vein it needs mentioning that the role of government in facilitating the successful transfer of technology should not be underestimated. Apart from being responsible for the economic framework of the recipient country, it also is capable of sending the right signals to industry and other sectors regarding promotion of R & D of environmentally sound technologies, or even determining patenting regimes, or other incentives or disincentives. One of the concerns of the developing countries, is how advanced technology once transferred is not 'fixed' and is capable of continuously evolving or being upgraded.

Assuming that SOA technology could be transferred to developing nations the question then arises as to who will fund this transfer, who will identify these environmentally benign technologies and whether a clearinghouse would be required to aid this process.

There are two broad measures which could be taken to facilitate international technology transfer process in the interests of developing countries. One is altering the broad macroeconomic conditions within which Flow A type technology occurs, at the international level so that the scale of flow increase significantly ; and within nations ensuring that macroeconomic conditions, encourage the absorption and use of the imported technology.

Secondly, there should be a greater emphasis on the Flow C type technology so that developing countries do not acquire 'fixed' technology but instead are capable of both generating and managing technical change. These issues may be dealt with in greater detail in a subsequent collaborative study.

1.3 Cross - Country Comparisons

There is growing concern globally, including in the developing countries that the energy intensive economics of the developed countries are no longer viable because of their adverse environmental impacts. At the same time, there is increasing recognition that adoption of measures such as improved energy efficiency and conserving energy, in other words, a "no regrets" policy serves the dual purpose of saving limited energy resources as well as containing GHGs emissions. The two different ways of abating CO2 emissions include (i) limiting sources that release CO2 and (ii) developing sinks that assimilate CO2. The first option includes improving fuel efficiencies, as well as fuel substitution, including use of of renewable energy sources.

In this chapter an analysis of the various technologies that can be adopted by the year 2000, to abate CO2 emissions has been undertaken. These technologies have been ranked by each country, on the basis of the specific costs of each technology, with the technology with the lowest specific cost accorded the highest rank. These specific costs have been estimated from the total costs for each technology (in 1990 US $) and the possible CO2 savings potential over the lifetime of the technology. It is assumed that all capital investment takes place in 1990 i.e., there is no phasing of investments.

Further, due to lack of adequate data on fuel costs and O&M costs in many of the countries in the study (with the exception of China and Brazil) these are not included in the cost estimates. Hence, the cost estimates are only indicative of the order of magnitude of the investments needed to limit CO2 emissions.

It must be pointed out at the outset that the notion of cost various across the country studies. In India and bangladesh, the capital costs of the technological options have been taken as surrogates for CO_2 abatement costs. Fuel and O & M costs are not included due to unavailability of data. Wherever applicable, the costs of the backstop technology has been subtracted and only incremental costs are used as indicators.

The China study, on the other hand, has computed the costs with fuel & O & M costs, as well as strictly capital costs. The Brazilian paper has estimated the cost of avoided carbon emissions from the consumers perspective, assuming the potential cost/benefit of a given technology substitution or measure. This is dependent on the price of the fuel and the costs of the new technology. An assumption of a social discount rate of 12% was used to evaluate the investment decisions. In particular the formula used is

$$\text{Cost of avoided Carbon} = \frac{\text{Value of energy expenses} + \text{net investment}}{\text{avoided annual carbon emissions}},$$

where net investment is the difference between annual investment cost of new technology and the old technology.

The total investment requirements have been worked out for each country by adding the product of specific cost and the estimated potential CO2 savings for each technology. On the basis of the specific costs and potential CO2 savings, the cost functions for abating CO2 emissions have been drawn. These cost-functions may be viewed as a supply function for CO2 abatements in each country [*].

Of all the countries in the study, China and India afford the largest potential for CO2 savings, i.e., 4175 and 2875 MT/C respectively. On the other hand, in Bangladesh from the available shelf of technologies which can be adopted by the year 2000 A.D. the potential for cumulative saving is about 75 M T-C only. It is reiterated that the savings of carbon in each case are computed over the lifetime of each technology and the cumulative savings are an aggregate of the same. Such computations could not be undertaken for Brazil, Iran, Japan, Korea and Thailand. A sector wise comparison of the technologies that can be introduced by the year 2000 follows.

Power Sector

A cross-country comparison reveals that in the electricity sector of India and Bangladesh, there is considerable scope for reducing the transmission and distribution losses. They range from 22% in India to 40% in

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[*] This statement is not strictly true, because "specific costs" are typically capital investment costs, rather than actual marginal abatement costs.

Bangladesh. If the losses were reduced to 16% by the year 2000 in India, an investment of $7.2 billion would be required and the potential reduction in CO_2 emissions is estimated to be 210 M T-C of carbon (assuming that the entire reduction in CO_2 emissions is attributable to reduced power generation by coal based thermal plants). On the other hand, if electricity authorities in Bangladesh aimed to reduce the T & D losses to 25%, an investment of $82 million will lead to a saving of 2.4 million tonnes of carbon (M T-C). In Bangladesh there is no coal based power generation (which is hydro, natural gas and oil based). For Bangladesh the present generation level (7732 GWh) was used to compute the CO_2 savings, assuming that all generation saved is attributable to natural gas based plants. If the likely generation in 2000 AD is taken as the reference, the potential savings in CO_2 emissions will be higher.

In China, improvement of energy efficiency in the power sector has been envisaged due to increase in the shares of Pressurized Fluidized Bed Boilers (PFB) and Combined Cycle Plants (oil based) which are more energy efficient than the conventional plants. An investment of $180 million in PFB and $192 million in Combined Cycle plants may result in savings of 9.5 and 5.2 M T-C respectively. In comparison, the gas based combined cycle plants replacing coal based plants in India would need an investment of $1.7 billion and save 82.5 M T-C.

In Thailand, the feasibility of electricity generation from agricultural wastes for rural industries has been identified as an option for limiting CO_2 emission, with replacement of wood charcoal and electricity (thermal based) by gas or electricity from agricultural waste gasifiers. The specific cost is computed to be \$38/tonne of CO_2.

Industrial Sector

In the industrial sector the scope for enhancing energy efficiencies is high in all the countries included in this study, although, the particular measures identified in each country differ. In the industrial sector in India, improved housekeeping, installation of energy efficient equipment, and better instrumentation may result in saving 88 M T-C, at an investment of about \$3.5 billion. In Bangladesh the package for efficiency improvements includes combustion control, process improvements, cogeneration, and simple retrofits, will require an investment of \$ 131.5 million and save 3.4 M T-C. In Brazil, the suggested package for industries includes better choice of electric motor (in terms of their size), appropriate design of the internal distribution electricity network, installation of small size transformers in parallel with the large ones, correction of load factor, requiring an investment of \$1 billion and saving 4.8 M T-C. The specific costs are as high as \$208.4/T-C.

The specific cost of reduction of CO_2 is the lowest for better housekeeping measures among all the measures identified for the industrial sector in both India and Bangladesh (\$8/tonne of carbon in Bangladesh and \$14 /tonne of carbon in India). This fact clearly highlights the attractiveness of introducing such simple measures.

In China the emphasis in the industrial sector, is on retrofitting existing industrial boilers and kilns, which will require an investment of $6.3 billion and result in CO_2 reduction of 252 million tonnes of carbon. The specific costs are $19 per tonne of carbon saved in the case of retrofitting boilers and $35 per tonne of carbon saved by improving kiln efficiency.

In all these countries the industrial sector uses a major share of the total energy supplies. Accordingly, steps to improve efficiencies in industry may result in considerable energy savings in absolute terms, and consequently reduction in CO_2 emissions.

Transport Sector

The transport sector in India consumes 24% of the total energy consumption. With a decrease in the share of railways in both freight and passengers transport, and in increased share of personal modes of passenger transport, the energy demand in this sector has increased substantially. Hence, the measures that have been suggested for possible implementation by the year 2000 are

(i) enhanced urban mass transport through increasing the bus fleet and introduction of metro rail system; and

(ii) Increased rail freight movement. The total investment of $48 billion will save 279 M T-C.

In Bangladesh, the best way to conserve energy in the transport sector is through improved road maintenance as it is the one most easily implemented. This would require an investment of $110 million and may save 1.2 M T-C.

The Brazilian case is interesting in that transport occupies a key place in the solution to minimize carbon emissions. The transport sector accounts for 32% of the carbon emissions. Fuel substitution (the highly publized alcohol programme), highway improvements, efficient diesel engines and improvements in vehicle efficiencies are the main options. The highway improvement programme will cost as much as $2954/T-C as compared to only $92/T-C in Bangladesh. However, it must be reiterated that these specific costs are not comparable. Improved urban transportation through construction of special lanes for buses will cost as much as $2147/T-C saved.

Residential Sector

In the residential sector improvements in energy efficiency of both cooking and lighting devices has been analysed. However, the devices considered and the fuels used differ across the countries. Improvements in cooking devices range from improved firewood chulha in India, to coal saving stoves in China, to unnat chulhas (based on woody biomass) in Bangladesh. The specific costs vary from $14/T-C saved in India to $9/ T-C saved in China and $5/T-C in Bangladesh, (again, the figures are not commensurable across the countries). It is interesting to note that essentially the same option will save only 2 M T-C in Bangladesh, 6 M T-C in India and as much as 305 M T-C in China. This difference between Bangladesh and India on one hand, and China on the other is due to the fact of the fuel used in the devices (wood and coal respectively), being different.

The lighting devices that have been considered also vary. In Bangladesh improved kerosene lamps (unnat koopi) is the feasible option, while in India the technologies identified that can be adopted by the year 2000 are fluorescents, both tubes and compacts. In Brazil too, experts feel that by the year 2000, the stock of residential lamps will comprise 50% improved incandescent, 30% fluorescents and 20% compact fluorescents. To achieve this, $1271 million investment will save 2.33 M T-C, with a specific cost of $545/T-C. In India, on the other hand, if we assume that it is possible to replace 50% of the incandescents by fluorescent, the specific investment cost is $12/T-C and if 50% incandescents are replaced by compact fluorescents, the specific investment cost is $85.82/T-C. The specific costs are much lower in India because a major share of the electricity saved is from coal (70%) and hence the carbon saved is larger. In direct contrast, in Brazil 90% of the electricity saved is from hydro implying a lower carbon saving. The difference in specific costs is also attributable to the varying approaches adopted in the two country studies. While Brazil considers tube fluorescents and compact fluorescents in conjunction with incandescents, the first two options have been considered separately in the India study.

Afforestation

One of the best ways of assimilating CO2 emissions is through afforestation. In India a stated policy objective is to afforest one-third of the land area by 2000, implying afforestation of 70 million ha in the next decade. On the other hand, China aims to afforest 16-17% of the land area, implying an area of 48-63 million ha under forest. In Bangladesh the potential area that can be afforested is 2.64 million ha. The specific investment costs range from $19.2/T-C in Bangladesh, $26.3/T-C in China, and $27/T-C in India. Again, comparisons of the specific costs across countries should be avoided.

The Brazilian case is unique. As high as 80% of the total carbon emissions are due to deforestation. However, unlike other developing countries, this deforestation is not strongly related to the energy use of fuel wood. It is primarily due to grazing, agricultural and logging activities. Experts from Brazil claim that afforestation/ reforestation "...with conventional relatively homogeneous plantations to sequester carbon in biomass may result in a relatively small part of the reduction of net carbon emissions". The short term emphasis should be to stem deforestation and reorientation of the electricity generation policy. The high priority assigned to hydro projects should be modified and thee pace of exploitation of the hydro potential in Amazonia should be arrested. The latter may imply an increase in carbon emissions because of higher thermal generation, but this increase will be more than compensated by the contribution to the overall policy to reduce deforestation.

In Thailand, energy plantations have been identified as a measure to limit CO_2 emissions since these would imply no emissions from deforestation for energy purposes. This measure may result in saving 11.9million T-C per year and the specific cost ranges from $54 to $63/T-C.

The cheapest options in the different countries vary. For example, in India coal washing is the cheapest in terms of specific cost per T-C saved. In China dissemination of coal saving stoves to rural households is the cheapest option, and in Bangladesh improvements in efficiency of the firewood chulhas has the lowest specific cost. In Brazil improved incandescents is the best option.

In Iran there are plans to improve efficiencies in electricity generation to increase the share of public transport in passenger movement, replace gasoline by LPG in buses, and afforestation, all of which will facilitate CO_2 reduction. However, cost estimates for the same are not available.

Similarly, the Korean economic development plan has laid down certain energy policy measures with a view to achieving the objective of a relatively clean environment. These include expansion of gas use in urban areas to replace existing fuel, i.e., anthracite, raising the proportion of low sulphur diesel and unleaded gasoline, and strict enforcement of environment standards for coal fired plants and coal briquette manufacturers. The costing of the above measures could not be undertaken.

The case of Japan is entirely different, in that not only is it the only developed nation among the countries included in this study, but also that due to intensive measures to conserve energy, industrial restructuring, and introduction of nuclear energy as well as LNG, CO_2 emissions declined at an average annual rate of 0.1% during the period 1973-85. However after 1987, Japan has witnessed further economic expansion marked by revival of energy intensive industries. Consequently, energy demand and CO_2 emissions have increased. To limit CO_2 emissions in the future, Japan must develop and introduce extremely advanced technologies, information on which is uncertain and limited. In light of this, the Japanese espouse that their principal contribution in abating CO_2 lies in transferring the already established technologies to other countries in Asia, which have yet to achieve Japanese levels of energy CO_2 intensities.

CHAPTER 2 : BANGLADESH COUNTRY PAPER

K.I. OMAR
and
I. HOSSAIN
Department of Chemical Engineering
Bangladesh University of
Engineering & Technology
Dhaka-1000
Bangladesh.

EXECUTIVE SUMMARY

Bangladesh is a small but populous country. With a per capita income of US $ 160 and a per capita commercial energy consumption of 56 kgoe, it comes at the bottom of the list of nations. Commercial energy account for only 30% of the energy consumed in Bangladesh. The current CO_2 emission in million tones of carbon is approximately 4.24. Bangladesh is therefore an insignificant polluter of the environment in terms of CO_2 emission.

There exists considerable potential of energy conservation in Bangladesh because of the existing low efficiency of energy utilization. The most significant is the electricity sector, which suffers from a staggering 40% system loss. A 15% reduction of system loss over a 10 year period has been considered. At a cost of Us $ 82 million, 2.4 million tonnes of carbon emission can be prevented. Similarly the industrial sector has a potential of saving 3.4 million tonnes of carbon emission using various technologies at an investment of US $ 108 million. These technologies are economically viable projects, i.e., a return on investment can be expected. The transport sector in Bangladesh consumes a large amount of commercial energy fairly inefficiently. Of the various reasons behind it, poor road maintenance is the most significant. A road maintenance program at a cost of US $ 110 million has been considered. This results in a saving of 1.2 million tonnes of carbon.

The rural residential sector consumes a large amount of woody biomass resulting in net deforestation. The combustion process (i.e. cooking) of biomass in stoves presently being used is highly inefficient. The distribution of improved stoves to rural households at a cost of US $ 10.6 million can save approximately 2.3 million tonnes of carbon. Similarly improved lamps can save 0.04 tonnes of carbon.

The biggest potential of fixing carbon is afforded by afforestation. At present 3.27 million acres of land remain deforested. An afforestation program of this land will cost US $ 1255 million, which will fix approximately 65.4 million tonnes of carbon. Besides these, several other miscellaneous measures can conserve energy and hence save carbon dioxide emissions.

To judge the merit of the various technologies in terms of investments, specific costs defined as investment divided by the carbon saved or fixed have been calculated. These are presented in the table below. On the lower side of investment required are the technologies of improved stove, housekeeping + operation and management and simple retrofit. On the higher side are the technologies of road maintenance and cogeneration. This paper discuss the calculation of specific costs for these various CO_2 emission reduction technologies and comments on the possibility of implementing therefore the year 2000.

Introduction

Bangladesh is situated in the north-eastern part of South Asia. It is a small country with an area of approximately 144,000 square kilometers. The country consists largely of the flood plains of the Ganges, Brahmaputra (locally called Jamuna) and the Meghna rivers which drain the Himalayas and flow into the Bay of Bengal forming the world's largest delta. Approximately one third of the land area is less than 10 meters above sea level and the country is plagued with annual flooding. With 60 percent of the land area under cultivation, Bangladesh's economy is predominantly an agrarian one. Agriculture contributes 40 percent to the G.D.P and employs 55 percent of the official workforce.

At present Bangladesh has become the most densely populated country (except the city states). According to the 1991 census Bangladesh's population is 109 million. The per capita income is around US $ 160/- (1 US $ = Tk. 36.5(1990)) and over 70 percent of the population lives below the officially defined poverty line (recommended calorie intake below 2122 Kcal/person/day).

The per capita commercial energy consumption of approximately 56 kg of oil equivalent per year is one of the lowest in the world. Commercial energy accounts for roughly 30 percent of the total energy consumption, the remaining 70 percent is met by traditional fuels. Table 1 shows the changes in per capita commercial energy supply over the years.

Tables 2 and 3 presents sectoral composition of GDP and Energy Intensity-GDP respectively. As is usual of all developing countries with a large agrarian economy, the contribution of the primary sector is large. The small growth in real per capita GDP (about 1 percent) reflects the slow growth of economic activities and the large increase in population (Table 3).

The current (1990) energy consumption is given in table 4. The CO_2 emission (in million tonnes of elemental carbon) is given in Table 5. As is evident, Bangladesh is an insignificant polluter of the environment in terms of CO_2 emission. The per capita consumption of commercial energy is so low that the projection of 1985-86 business-as-usual scenario (see Table 3) energy consumption for the year 2000 results in an unrealistically low figure. Table 6 presents the planning commission's projection of energy demand for the year 2000. It takes into account national aspiration and goals with regard to economic growth and a reasonable standard of living for its vast millions.

This paper investigates the possibilities of lowering carbon dioxide emissions with a view to reducing global warming. The following sections discusses the various strategies of energy use including cost analysis for limiting carbon dioxide emissions.

Electricity Sector

The installed electricity generation capacity as of June 1990 stood at 2179 MW, of which 1374 MW is suitable for base load operation and the remaining 805 MW is suitable for intermediate and peak load generation (2). The total electricity generated in 1990 was 7732 GWh, the fuel used was predominantly (84.3%) natural gas.

The thermal efficiency of the generating plants (mostly steam thermal units) is quite low (approximately 25 percent).

There are two widely accepted components of the system loss, the technical loss and the non-technical loss. Different components of technical losses and their approximate values in Bangladesh are as follows (2)

i)	Stations use	- 5 percent
ii)	Transmission loss (230 and 132 KV)	- 5 "
iii)	Sub-Transmission loss (33 V)	- 7 "
iv)	Distribution loss (11 KV and 0.4 KV)	- 8 "
		25 percent

Non technical losses consist of the following components: (i) inaccurate metering (ii) non-billing (iii) under billing (iv) tampering of meter-reading and (v) pilferage/theft. Approximate values of non-technical losses are about 14-15 percent. The total system loss in the country is therefore approximately 40 percent, one of the highest in the world.

Recently the Power Development Board has taken up a project to reduce the system losses to 25 percent by the year 2000. The cost estimate for this 15% reduction was given as Taka 3000 million.

The breakdown of electricity generated in 1990 is as follows

	System Losses	
Hydro	884 GWh	(11.43%)
Natural gas based	6615 GWh	(84.26%)
Petroleum liquid fuels	333 GWh	(4.31%)
	7732 Gwh	

Even if the reduction of system loss to 25 percent is based on the present level of production, 8.8 million tonnes (2.4 million tonnes of carbon) of CO_2 emission can be prevented assuming natural gas based electricity generation. This gives a specific cost of US $ 34.3 per tonne of carbon.

Industry

The industrial and power generation sector in Bangladesh operates at a low level of efficiency. This comes about mainly from a low level of maintenance. The Ministry of Energy, with financial help from the World Bank, studied the conservation potential of various industries. The Ministry of Energy also established an Energy Monitoring Unit (EMU), whose role is to investigate, initiate and carry out energy conservation measures. This study included energy audits in the industrial and power sector and resulted in a report entitled "National Industrial Energy Conservation/ Substitution program", in March 1986 (3). In this report a long term energy conservation strategy was outlined. It was estimated that US $ 108 million could be invested towards energy efficiency measures. This would result in an annual savings of US $ 38 million or in other words the project will have a payback period of 2.8 years. Tables 7-10 and Appendix A provides the summarized details of the various technologies which can be used to enhance energy efficiency.

Table 7 gives the energy and cost savings along with investment requirement and payback period for various technologies. The difference between gross and net savings in Table 7 is the annual operating costs involved. In column 6 of Table 7, the economic value of energy savings is based on estimated LRIC (Long run incremental cost) which is the same as long run marginal cost. These are presented in Appendix A. Details of various industries are given in Table 8. Tables 9 and 10 show the time frame for energy savings and the incremental investment required respectively. To simplify calculations it has been assumed that the proportion of oil, gas and electricity in the energy savings as listed in Table 8 for different industries is in the same proportion as that given in the Total consumption figures. Furthermore traditional fuel has been lumped into commercial energy which introduces only a slight error. The carbon saved can be found by adding all the energy savings over the years (Table 9).

Similarly the total cost of the various technologies can be found by adding all the investments over the years (Table 10). This gives specific costs of US $ 6.3, 10.3, 12.9, 28.4, and 138 for housekeeping + operation/management, combustion control, retrofit + others, process improvement and cogeneration respectively. The costs shown in all Tables uses the June 1985 dollar. Assuming that the costs of these technologies have been affected only by inflation, one can arrive at 1990 prices by incorporating inflation into the specific costs. Of the technologies listed, housekeeping has a low specific cost, is the easiest to implement, and can be started immediately if funds are available. Combustion control and retrofit are equally attractive and can also be started as soon as funds are available. Process improvement requires considerably more investment and also requires the purchase of technologies. This can be started by 1995. Cogeneration, though an attractive proposition in the modern industry, is much less attractive in terms of limiting CO_2 emission as evidenced by the high specific cost. It must be emphasized that all these technologies have been identified in this study (3) as economically viable projects.

Even though there exists scope of energy conservation in the industrial sector, it is small in absolute terms because of the low level of industrialization in Bangladesh. Paucity of investment funds prevent industrialists from searching for energy efficiency measures.

Transport

Energy conservation in the transport sector was studied by the Planning Commission as a part of an extensive project entitled "Bangladesh Energy Planning Project" (BEPP). In a report submitted on June 1985, the potential of energy conservation was analyzed and the following three methods were suggested (4)

i) Better management of transport activities

ii) Modal shift in transportation of passengers and/or freight and

iii) Use of alternative fuels (i.e. fuel substitution)

Of these, points i and ii if implemented will result in energy conservation and are therefore relevant to limiting CO_2 emission. Item i has been sub-divided into the following four areas

i) Improved vehicle maintenance

ii) Improved driving

iii) Appropriate size composition of vehicle fleet, and

iv) Better road maintenance

Of these, vehicle and road maintenance holds the maximum promise and are readily implementable . Roads in Bangladesh are built below international standard. Moreover these are not maintained. According to this study (4) between 20-40% fuel efficiency is attainable if international standard roads are constructed. About existing roads, this study was of the opinion that if properly maintained some fuel saving will result. According to Roads and Highways (R&H) Department (5), proper maintenance (i.e. carpeting every 5-6 years) requires 2 million Taka per kilometer. The low maintenance budget of R&H allows only pothole repair and minor sealing every 2-3 years at a cost of 0.7-0.8 million Taka. R&H spends approximately 1.5 million Taka every 5 years. They therefore need a supplement of Taka .5 million per kilometer to carpet all roads every 5 years. Therefore Taka .5 million is the incremental investment needed to properly maintain roads. If this additional fund is made available, better road maintenance will be possible. Furthermore such work can start immediately. Bangladesh has about 5000 kilometer of roads consisting of National Highways, Regional Highways and Feeder Roads. If all roads are carpeted every five years then 1000 kilometer of road have to be carpeted each year at a cost of 2000 million Takas. It is assumed that a 10% saving of diesel and gasoline is possible. For a program of 10 years starting 1992, the cost at 1990 prices using a discount rate of 5% amounts to US $ 110 million. The amount of carbon saved due to the enhancement of fuel efficiency can be evaluated by adding up the saving for each year. In the first year only a 2% saving has been assumed because only 20% of the total investment would have been made or in other words only 20% of the roads would have been carpeted. From the fifth year onwards the full 10% potential will be realized. The specific cost for the road maintenance project is US $ 93 per tonne of carbon. The high specific cost should not be discouraging because the social benefits of such a project can hardly be over emphasized. For example well maintained roads will decrease accidents and encourage tourism and commerce.

Residential (rural)

The rural residential sector consumes a large quantity of fuel due to the fact that thermal efficiency of combustion of biomass (i.e. cooking) is between 8-10% only. Table 11 shows the availability of biomass by type (2). Woody biomass are those which comes from reserved and village forests and constitute 16% of the total biomass used for fuel. These are the only type of biomass considered here because woody material are renewable only on a long term basis. The problem of low efficiency has been studied extensively and stoves of higher efficiencies have been developed. It is envisaged that through an extension program, 500,000 unnata chulhas (improved stoves) and unnata koopis (improved lamp) would be distributed to rural households each year for the next 10 years. It is worth mentioning that koopis will conserve commercial energy (i.e. kerosene). The 1990 cost of delivering each Chulha has been estimated (2) to be Tk. 100/- (Tk. 50+Tk.50, Chulha cost + extension cost). The 1990 cost of each koopi is Tk. 10. A typical household (or each Chulha) consumes approximately 1200 kg of biomass per year. It is assumed that 75% of the chulhas are used and each Chulha uses 50% less biomass to perform the same heat duty. The life of these clay chulhas are assumed to be two years. Similarly 75% of the koopis are assumed to be used and each koopi uses 25% less kerosene. The life of each koopi is two years. Each koopi consumes 25 kg of kerosene per year.

Using a discount rate of 5% and working in constant 1990 dollars the cost of the Chulha project at 1990 prices comes to US $ 10.6 million. The amount of carbon saved (carbon content of biomass 0.5) over the 10 year period is 2.3 million tonnes. The specific cost is therefore US $ 4.7 per tonne of carbon saved. Similarly the specific cost for the koopi project is US $ 26.5 per tonne of carbon saved.

Afforestation

The present land area under tree cover in Bangladesh is precariously low, about 8 percent of the total area. A number of reasons have contributed to this (a) large increase in population (b) increase in demand for agricultural land (c) urbanization and industrialization and (d) illegal felling.

According to government estimates (6), 3.27 million acres of land are denuded of forests. Since there is no other use of this land other than the creation of forests, a concerted afforestation effort should be made. Assuming a 50 percent survival rate for plantations, the area to be brought under tree cover becomes 6.54 million acres. It has been estimated that a per acre investment of Taka 7000/- is required for afforestation. The total investment required for a 10 year program amounts to Tk. 45.8 billion (Tk. 7000 x 6.54×10^6). Assuming a total biomass of 40 tonnes/acre, 3.27 million acres would have $40 \times 3.27 \times 10^6 = 130.8$ million tonnes of biomass. Taking carbon content of wood to be 50 percent, 65.4 million tonnes of carbon can be fixed by the above afforestation program. The specific cost is therefore US $ 19.2 per tonne of carbon fixed.

At present approximately 83 percent of biomass fuel is supplied by agricultural residue, animal dung and recycle biomass. Village woodlot supply 14 percent of the biomass used for fuel use, only 2 percent of firewood comes from government forest lands. If an efficient system of management can be installed, the government owned forests can supply the two percent of firewood thus avoiding net deforestation.

Forests therefore can be maintained for the purpose of CO_2 assimilation. However afforestation programs and management of forest resources need careful planning and monitoring.

Miscellaneous

In a recent study (2) several other options for reducing energy consumption has been mentioned. These are

(a) Closing down city's shopping centres between 5-10 P.M. in winter (October-March) and 6-10 P.M. in summer (April-September) will reduce the peaking load

(b) Adequate automatic electronic switch control for road illumination will save electricity consumption significantly

(c) Electronic Fan Regulators will save electricity significantly

(d) Increase of conductor size in busy load centres will conserve energy

(e) Appropriate power factor will conserve electricity

It is difficult to estimate readily how much energy will be conserved by these measures. Since these measures can be undertaken at very little cost the specific cost would be fairly low.

Conclusions

Table 12 presents the summary of specific costs discussed in this paper. Figure 1 presents, the cumulative carbon saving versus specific costs. On the low side are the technologies of rural residential, industrial housekeeping and simple retrofit. On the high side are road maintenance and cogeneration.

Table 1 : Population and per Capita Commercial Energy Availability

Year	Population (Million)	Annual growth rate	Urban (%)	Per-Capita Commercial Energy	Growth Rate in per Capita Commercial Energy
1980-81	89.9	--	13.8	1.30	--
1985-86	101.7*	2.5	19.4	1.52	3.18
1986-88	106.6*	2.4	23.5	1.76	7.61

Source . REF. (1,8)

* Projected

Table 2 · Gross Domestic Product (At constant 1984-85 Taka)

Year	GDP Taka in Millions	Primary %	Secondary %	Tertiery %	GDP rate of growth
1980-81	357496	-	-	-	-
1985-86	424593	41.3	9.7	49.0	3.5
1987-88	455135	38.4	9.8	51.8	3.5

Source : Ref. (8)

Table 3 : Per Capita GDP and Energy Intensity

Year	Per Capita GDP (1984-1985 Taka)	Rate of growth of P.C. GDP	Energy-GDP Intensity kJ/Taka	Rate of change of Energy-GDP Intensity %
1980-81	3977	-	0.327	-
1985-86	4175	1.01	0.364	2.17
1987-88	4270	1.13	0.412	6.39*

* The high values of GDP/Energy intensity is due to the fact that several power plants and a large fertilizer factory came on line during 1985-88.

Table 4 : Current Fuel Consumption (1990)

	Coal 10^3 Tonnes	Oil 10^3 Tonnes	N. Gas 10^6 ft^3	Biomass 10^3 Tonnes
Agriculture	-	258	-	-
Industry	350	218	71,443	7,149
Power Gen.	-	205	70,000	-
Transport	95	587	-	-
Residential	-	553	9,415	31,886
Commercial & Others	13	-	3,142	121
Total	458	1821	154,000	39,156

Source (2)

Table 5 : Current CO_2 Emissions (1990)

(in million tonnes of carbon)

	Coal	Oil	Natural Gas	Woody Biomass
Agriculture	-	.216	-	-
Industry	.225	.183	.64	.67
Power Generation	-	.172	.93	-
Transport	.075	.492	-	-
Residential	-	493	.12	-
Commercial (others)	.010	-	.042	-
Total	.31	1.526	1 73	.67

Table 6 · Energy Demand for 2000

(in MTOE)

	Coal	Oil	N. Gas	Biomass
Agriculture	-	0 671	-	-
Industry	0.886	0.300	3 663	3 524
Power Generation	-	0 230	4.886	-
Transport	0.109	1.153	-	-
Residential	0.071	0 550	0 696	11.183
Commercial (others)	0.085	-	0.232	0 107
Total	1.151	2.904	9.477	14.814 - 14.83

Source (2)

Table 7 National Energy Efficiency Improvement Potential by Technology

E.C. Option	National Energy Savings (10^{12}KJ/Yr)	Gross National cost Savings[1]) ($MM/Yr.)	Net National Cost Savings[1]) ($MM/Yr.)	Gross National Cost Savings at 12/85 Energy Prices[4] ($MM/Yr.)	Economic Value of Net National Energy Savings at Economic ($MM/Yr.)	National[6] Investment ($MM)	Payback Period[3] (Years)
Pure Energy Savings							
Housekeeping	4.85	6.26	6.26	6.42	10.86	6.5	1.05
Operation/ Maintenance	0.97	1.53	1.48	1.58	2.07	2.2	1.51
Combustion Control	4.53	9.36	8.51	9.43	11.91	9.9	1.17
Simple Retrofits	1.21	1.73	1.59	1.79	2.33	2.8	1.75
Turbine Heat Rate	0.10	0.30	0.30	0.32	0.48	0.6	2.03
Electrical	0.44	0.95	0.95	1.07	2.36	1.9	2.01
Process Improvement	1.80	3.52	3.39	3.61	4.39	7.8	2.30
Sub-Total:	13.90	23.65	22.48	24.22	34.40	31.8	-
Cogeneration	5.15	25.18	15.66	28.61	32.84	76.0	4.85
Fuel Switching[2]	0.00	68.71	45.57	68.71	48.56	25.4	0.56
TOTAL	19.05	117.54	83.72	121.54	115.80	133.1	-

Notes (1) Financial value of energy savings or oil displacement, based on actual in country costs, June 1985. The difference between the gross and net savings is the annual operating cost.

(2) Fuel switching has no energy savings per se but does displace imported oil, Equivalent oil displacement is 15.1 PJ.

(3) Based on financial savings.

(4) Gross national cost savings, based on Dec 1985 gas, oil, electricity and alternate fuel prices

(5) Economic value of energy savings, based on estimated LRIC costs for gas and electricity; oil at 26.76 per BOE; alternate fuels at coal equivalent value. For economic value at alternate prices, see Appendix A.

(6) Includes both foreign and local costs, June 1985 dollars

Source : Ref. (3)

Table 8· Estimated Energy Savings Potential by Industry Sector

Industrial Sector	Savings Potential (10^{12} KJ/Yr								
	Pure Energy Saving						Cogeneration[2]	Fuel Switching[3]	Total[4]
	Oil	Gas	Electric	Subtotal	Traditional	Total			
Fertilizer	0.01	3.03	0 00	3.05	0.00	3.05	0.00	(0.07)	3.05
Power	0.90	0.97	0.00	1.87	0.00	1.87	0 00	(6.93)	1.87
Other Minerals[1]	0.08	0.46	0.01	0.54	1.23	1.77	0.00	(0.51)	1.77
Rice Milling	0.00	0.00	0.09	0.09	1.67	1.76	0.00	(0 00)	1 76
Paper	0.93	0.12	0.07	1.12	0.09	1 21	0.09	(4.19)	1 30
Sugar	0.02	0.00	0.02	0.04	0.84	0 88	0 00	(0.09)	0.88
Food	0.06	0.10	0.04	0.21	0.34	0.55	0 47	(0.28)	1.02
Tea	0.15	0.07	0.01	0.23	0.23	0.45	0.04	(0.43)	0.49
Metals	0.41	0.00	0.02	0 43	0.00	0 43	0.00	(1.48)	0.43
Jute	0.08	0.13	0.07	0.28	0 07	0 35	2.27	(0 35)	2 62
Textiles	0.04	0.18	0.07	0.29	0 02	0.31	1.67	(0 16)	1.98
Cement	0 00	0.12	0.01	0 13	0.00	0 13	0 00	(0 00)	0 13
Glass	0.03	0.00	0.00	0 03	0 00	0.03	0 00	(0 20)	0 03
Miscellaneous	0.12	0.24	0 05	0.41	0.69	1.10	0 61	(0 38)	1.71
Total	2.84	5 39	0.44	8 71	5.19	13.89	5.15	(15 10)	19.05

Notes : (1) Largely brick
(2) Energy Saving component only, does not include fuel switching component
(3) Fuel switching has no energy savings per se. Equivalent imported oil being displaced is shown for comparison purposes only but is not included in totals
(4) Does not include fuel switching

Source : Ref. (3)

Table 9 · Estimated Time Frame For Energy Conservation Implementation[1]

(Estimated energy savings, 10^{12} Kj/yr)

EEI Option	Year 1	2	3	4	5	6	7	8	9	10	11	12	13
Pure Energy Savings Housekeeping	2.91	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81	5.81
Combustion Control	0.00	1.51	3 02	4 53	4.53	4.53	4.53	4 53	4.53	4 53	4.53	4.53	4.53
Simple Retrofit	0.00	0.01	0 11	0.20	0.31	0 35	0.38	0.38	0 38	0.38	0.38	0.38	0.38
Process Improvement	0.00	0.00	0.00	0.00	0 64	1.27	1.91	2 54	3 18	3.18	3.18	3.18	3.18
Subtotal	2.91	7 33	8.94	0.54	11.29	11.96	12 63	13.26	13 91	13.90	13.90	13.90	13.90
Cogeneration	0.00	0.00	0.00	0 52	1 03	1 55	2 06	2.58	3.09	3.61	4.12	4.64	5.15
Total :	2.91	7.34	8.94	11.06	12.31	13 51	14 68	15.83	16.99	17.50	18.02	18.53	19.05

Notes : Estimate is based on 1983/84 levels of energy consumption.

Source Ref. (3)

Table 10 : Estimated National Investment Requirements by year[1]

(Yearly incremental investment[2] \$ million)

EEI Option	Year 1	2	3	4	5	6	7	8	9	10	11	12	Total
Pure Energy Savings Housekeeping	2.2	3.7	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combustion Control	1.2	3.1	3.1	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9
Simple Retrofit	0.00	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Process Improvement	0.0	0.0	1.20	3.1	3.1	2.4	2.4	0.0	0.0	0.0	0.0	0.0	12.2
Subtotal	3.4	7.0	7.4	5.8	3.2	2.5	2.4	0.0	0.0	0.0	0.0	0.0	31.8
Cogeneration	0.0	0.0	1.9	3.8	5.7	7.6	9.5	9.5	9.5	9.5	9.5	9.5	76.0
Total :	3.4	7.0	9.4	9.6	8.9	10.2	12.0	9.5	9.5	9.5	9.5	9.5	107.7

Notes : 1. Based on 1983/84 levels of energy consumption

2. June 1985 dollars.

Table 11 : Supply of Biomass Fuels in Bangladesh in 1981

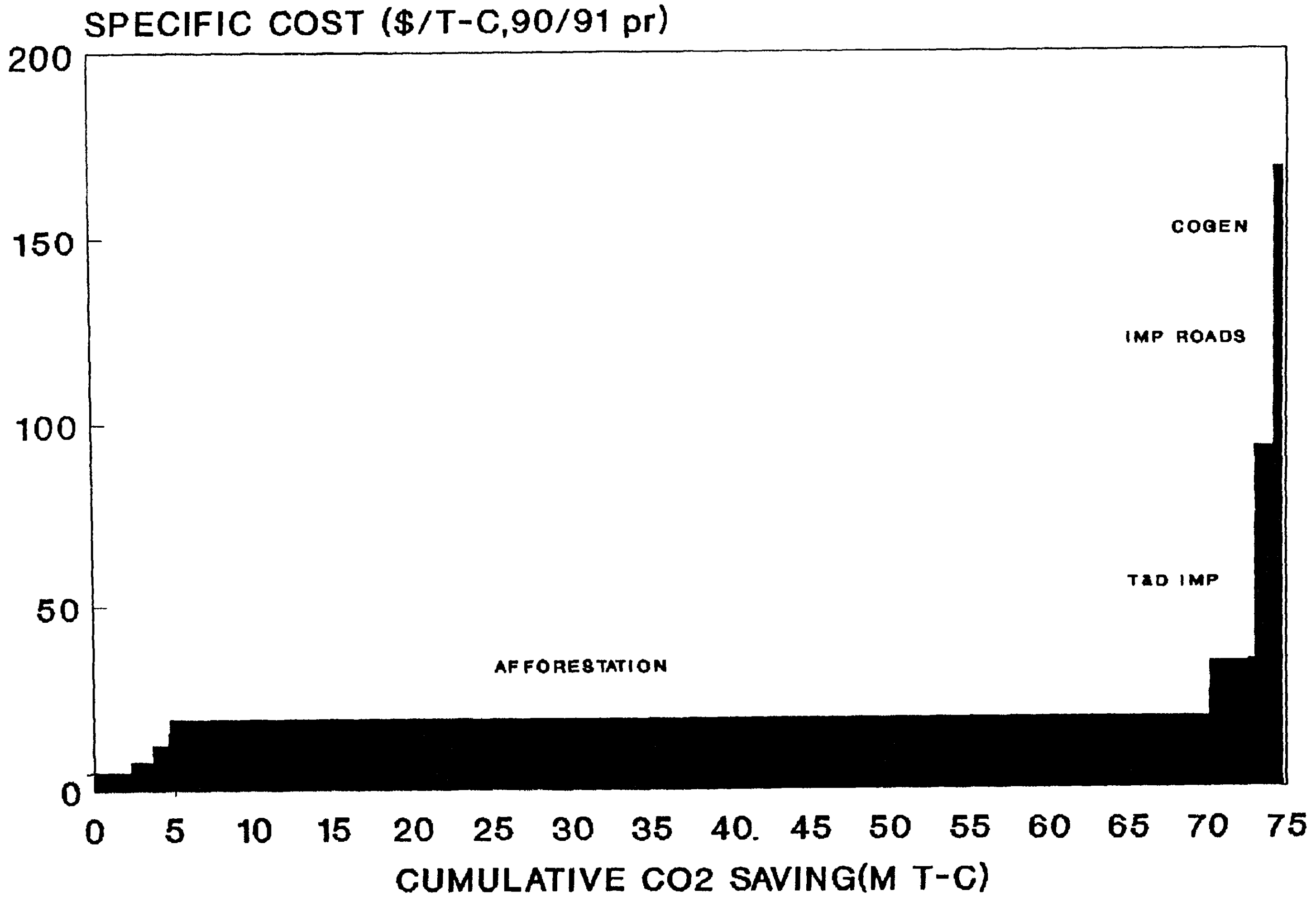
Type of Land	Area million acres	%	Biomass Fuels		
			Million tonnes	Peta Joule	%
Forests	5.41	15.30	0.68	10.30	2.15
Not available for cultivation	6.36	18.00	0.08	1.20	0.25
Village Forests	0.74	2.10	4.66	65.60	13.70
Culturable Wastes	0.62	1.80	0.15	2.00	0.41
Current Fallow	1.40	4.00	0.35	4.70	0.98
Net Crop	20.77	58 80	23.08	288.48	60.20
Total Area	35.33	100.00	29.00	372.28	77 69
Livestock (20.5 million head)			6.70(dung)	77.72	16.21
Recycle Biomass			2.30	29.30	6.10
Total			38.00	479 30	100.00

Source : Ref. (2)

Table 12 : Specific Cost of Technologies for Limiting CO_2 Emission

Technologies	Carbon Saved/Fixed MT	Investment Required M$	Specific Cost $/T
Electricity Sector			
T & D Loss	2.4	82.2	34.3
Industry Sector			
Housekeeping + Operation and Management	1.4	10.78	7.7
Combustion Control	0.96	12 09	12.59
Simple Retrofit	0.07	1 1	15.77
Process Improvement	0 43	14 93	34.73
Cogeneration	0.55	92.809	168 74
Transport Sector			
Road Maintenance	1.18	110.0	93.0
Residential (rural)			
Unnata chula	2.3	10 6	4.7
Unnata Koopi	0.04	1.06	26.5
Afforestation	65.4	1255	19.2
Miscellaneous	-	-	-

COST OF ABATING CO2 IN BANGLADESH



APPENDIX-A

ECONOMIC VALUE OF ENERGY SAVINGS UNDER DIFFERENT PRICES SCENARIOS

	National Energy Savings (PJ/yr)	Net Nat'l. Cost Savings ($mm/yr)	National Investment ($mm)	--------------Economic Value of Fuel Savings($mm/yr)---------							
Quick Fix	4.85	6.26	6 54	10.06	10.86	10.67	10.15	9.63	9 32	10 86	10 86
Operation, Maintenance	0 97	1 48	2.23	1 72	2 07	2.01	1 83	1 65	1 54	2 07	2 07
Combustion Control	4.53	8.51	9.92	11.56	11 91	11 57	10.60	9.63	9.05	11.91	11.91
Simple Retrofit	1.21	1 59	2.79	1 77	2.33	2.25	2.02	1 79	1 66	2 33	2.33
Process Improvement	1.80	3 39	7 78	3 74	4.39	4.21	3 70	3.18	2 87	4 39	4 39
Turbine HR	0 10	0 30	0 61	0.48	0 48	0 44	0.36	0.27	0 21	0 48	0 48
Electricity	0 44	0 95	1 91	1 92	2.36	2 36	2.36	2 36	2.36	2 95	1.67
	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	-----
Subtotal Pure Energy	13.90	22.48	31.78	31 25	34 40	33 51	31.02	28.51	27 01	34 99	33.71
Cogeneration	5 15	15 66	76 00	32 72	32.84	30 43	23 62	16 80	12 71	32 85	32 85
Fuel Switching	(15 10)	45.57	25 35	53 08	48 56	44 03	31 19	18.36	10 66	48 57	48 57
	=======	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Total	19 05	83 72	133 13	117 05	115 80	107 97	85 82	63.68	50 38	116 41	115 13
Oil	-	-	-	4 55	4 55	4 25	3 40	2.55	2 04	4 55	4 55
Industrial gas	-	-	-	1 22	1 27	1 27	1 27	1 27	1 27	1.27	1 27
Alternate	-	-	-	2 41	2 41	2 41	2.41	2.41	2 41	2 41	2 41
Electricity	-	-	-	4 34	5 34	5.34	5.34	5.34	5 34	6 68	3 78
Bulk gas	-	-	-	0 45	1 16	1 16	1.16	1.16	1 16	1 16	1.16
Oil	-	-	-	26 76	26 76	25 00	20 00	15 00	12 00	26 76	26 76

Source Ref (3)

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CHAPTER 3 : BRAZIL COUNTRY PAPER

Jose Roberto Moreira
Secretariat of Science and Technology
Federal Government, Brasilia, Brazil

Gilberto de M. Jannuzzi
Department of Energy
University of Campinas, Campinas, Brazil

Alan D. Poole
Ecotropic, Rio de Janeiro, Brazil

David Zylberztajn and Juliana Fries
Institute of Electrotechnology and Energy
University of S. Paulo, Sao Paulo,Brazil

Executive Summary

The paper seeks to evaluate the cost of avoiding CO_2 emissions in Brazil using new technologies for energy production and energy consumption. The question regarding CO_2 emission from deforestation is object of a very general discussion and is included since it is the most significant source of CO_2 emission in Brazil. Nevertheless no precise evaluation is performed.

Existing energy-related emissions by consuming sector and fuel are analyzed and official baseline energy projections made to the year 2000 are described. Twenty two technical changes are analyzed, mostly dealing with energy end-use in the residential, industrial, commercial, public and transport sector. On the energy supply the use of ethanol a fuel to replace gasoline has its costs of CO_2 avoidance quantified. The scale of possible reductions in CO_2 are also estimated.

Costs are found to be negative for 15 of the 22 technologies investigated. The most economically advantageous reduction in CO_2 emissions occurs through the use of better, already available technologies for lighting in the commercial sector. Such results were achieved taking into consideration only the cost differences in the initial investments between the new and in-use technologies and between the operational costs, including electricity and fuel saved. Other advantages, which are many, were not accounted for and may modify the overall net economic costs of CO_2 abatement of such alternatives.

Introduction

The emphasis in this paper is on CO_2 emissions, the principal greenhouse gas (GHG) of which Brazil is an important contributor in the world. It is widely recognized that the country's largest source of CO_2 emissions is the clearing of forest land for other uses. Quantitative estimates of this are a lively source of debate so precision is impossible. Despite the preponderance of deforestation on CO_2 emissions, this paper will concentrate on fossil fuel emissions and the possibilities for their reduction . This is in order to maintain a certain consistency, with very limited time and with the other country studies in this series. However some very broad elements of a policy to drastically decelerate deforestation and its costs will be outlined as well as potentially critical connections with energy policy, involving in the first place the charcoal industry and the expansion of hydroelectric capacity in the Amazon/Tocantins basin.

Contemporary CO_2 emissions sources

The total energy consumption in Brazil in 1990 reached 158.7 Mtoe, from which 56.5 Mtoe (36%) was from fossil fuel,60.3 Mtoe (38%) from hydroelectricity and 39.3 Mtoe (25%) from biomass. CO_2 emissions from the combustion of fossil fuel in 1990 reached approximately 57 Mt of C. Hydroelectricity can be responsible for the emission of some amount of CO_2 and other GHG if we take into account the amount of energy required for dam erection and/or biomass decomposition induced by water flooding for reservoirs. A detailed calculation can be carried out to quantify these emissions but since the amount is small compared with thermoelectricity production we will assume in this paper that CO_2 from hydroelectric plants is zero. CO_2 produced from biomass when burned for energy production requires a more detailed analysis. In a country like Brazil with a large surface area, a low population density when compared to other developing countries and with a tropical climate, the average rate of biomass growth is often much higher than its consumption for energy purposes[1].

Thus, firewood used for cooking or small farm processing of output, mainly in rural areas should not be understood as a basic deforestation process in Brazil. Deforestation related to energy use generally only occurs when there is an intensive use of biomass for industrial energy or residential use in medium or large size cities. Most of the houses in such cities use Liquid Petroleum Gases (LPG) for such end-uses. Accurate information about how firewood is being used in rural and urban areas is not available; thus we will assume that 20% of the biomass used in the residential sector should be counted as a source of deforestation.

For other uses we assume the following:

charcoal - only 1/3 of charcoal comes from plantations, however not all the charcoal which comes from native forests is responsible for the deforestation, which may be due to other causes. Just how much charcoal stimulates deforestation is highly polemical. Just to signal the issue we assume rather arbitrarily that 1/4 of the native forest used is not a cause of deforestaton but a result (its CO_2 emissions are attributed to general deforestation). Thus overall, 50% of charcoal fuelwood does not add CO_2 to the atmosphere;

other industry - the fraction of fuelwood coming from deforestation varies widely from industry to industry. It is assumed that 50% does not add CO_2 to the atmosphere. Pulp mill residues are assumed to contribute no net CO_2 to the atmosphere;

farm non-residential use - this use of fuelwood tends to be small-scale and dispersed with a deforestation impact similar to rural residential. It is assumed that 80% of this use does not contribute net CO_2 emissions. All sugarcane products (alcohol and bagasse) are assumed to result in no net CO_2 emissions. This is a simplification comparable to the treatment of hydroelectricity.

Thus, in 1990 the total amount of C added to atmosphere from biomass combustion was 9 Mt. Adding this amount with the previous figure obtained from fossil fuel combustion, total C emissions reached 66 Mt in 1990. Table 1 displays total energy use in Brazil in 1990. Table 2 provides socio and economic information.

Energy scenario

A detailed study was recently performed by an official working team [2] to forecast Brazilian energy demand in the year 2000 and 2010. The model is based on: a) the demand growth of energy services in different sectors of the economy; b) the coefficients of energy required for these energy services and c) estimates of the share of each energy source by the consumption sectors.

The forecast took into account two different hypotheses regarding economic growth, as shown in Table 3. One of the scenarios labeled as "business-as-usual" assumes that the same political and economic constraints which exist today, persist in the energy sector, including the price policy. Under these assumptions final energy consumption will increase, in the next 20 years at a rate just a little slower than the rate of growth of GNP yielding crescent participation of electricity and oil derivatives.

Opportunities to improve the energy forecast in comparison with the business - as - usual scenarios were identified [2]. They are:

- energy conservation;
- more efficient use overall of energy resources;
- development of new institutional conditions to enhance efficiency and competition as well as more opportunities for private enterprise participation;
- change in the energy consumption profile in a way favourable to open more space for the use of alternative sources of energy, mainly the renewable and decentralized ones, in all cost-effective, environmentally sound and socially rewarding uses.

Under this new view an alternative development scenario was built, to exploit all the opportunities listed above. Energy results from one of these scenarios is shown in Table 4.

A comparison between the alternative and business-as-usúal scenarios, shows that the major difference is a reduction in the total amount of energy supply, induced by more rational use. This is strongly reflected in the amount of hydroelectricity required which is reduced from 170.4 million toe to 126.5 million in 2010 as well as in the amount of oil used that is reduced from 156.7 to 118.1 million toe. This last reduction is explained by the price increase of oil derivatives induced by a gradual increase in the international oil price to US$ 25.00 per barrel in 2000 and US$ 35.00 in 2010.

The alternative scenario shows an increase in the natural gas share to 6% when compared with "the business - as - usual" as well as a larger participation of sugarcane products (5% more) since alcohol production is slightly increased and sugarcane bagasse will be used in electricity generation. Firewood and charcoal are also promoted by means of more emphasis on forest plantations.

To provide a better understanding of the alternative scenario used in this paper Table 5 shows a profile of the different sources of energy and Table 6 the final use in different sectors of the economy.

The electricity sector

Electricity supply

Electricity generation in Brazil is dominated overwhelmingly by hydro. Of the total public utility generation of 236 TWh in 1990, 228 TWh or 95.3% was from hydro [3]. The participation of hydro in private "auto-generation" is much lower, about 1/3, but this category is very small, only 4% of the public utility generation. Thus about 94% of Brazil's electricity is generated from hydro. (Note that hereafter, unless otherwise specified quantities cited will refer to the public utility system).

Hydroelectricity is not completely free of greenhouse gas (GHG) emissions. The processing and/or transport of large quantities of construction material involves emissions, as do the areas inundated for reservoirs (CO_2 from cleared vegetation, CO_2/CH4 from decomposing organic material in the reservoir). These emissions have never been quantified for Brazil, but they will nevertheless be very small relative to any fossil fuel over the lifetime of the plant [4].

The electrical sector's current expansion plans to the year 2000 will approximately maintain this profile of generation, with a very small increase in thermal generation [5]. Unexploited resources in Brazil are sufficiently large that approximately 90% of generation needs, through the year 2010 were projected to be met in the last strategic planning document of the sector [6]. Since that time increasing local social-environmental costs and constraints may have eliminated some potential or reduced the practical rhythm of its exploitation (which in Amazonia was projected to be very intense indeed). In partial compensation, projected consumption growth, even in "business-as-usual" scenarios is lower today given the macro-economic problems of the country. As a consequence, the issue of direct GHG emissions in medium-term electrical sector planning is not nearly as significant in Brazil as in almost all other larger developing and industrialized countries. The average CO_2 emission for electricity generation in developing countries is about 170 kg of carbon (C) per MWh; in Brazil it is about 9 kg C per MWh [7].

The resolution of other high priority problems may even lead to adjustments in existing policy which result in slightly lower hydro participation and hence on balance, modestly higher direct carbon emissions per MWh through the year 2000. These problems include:

a) the profound financial crisis of the sector and the high cost of capital investment (hydroelectric plants are capital intensive);

b) the enormous market uncertainty confronting supply planning (larger hydro especially requires extended lead times);

c) the need to attract more private sector investment, especially in generation;

Any changes resulting from such strategic shifts would be small. To begin with, the time horizon (2000) is relatively short given the long lead times of larger hydro capacity. Much of the hydro capacity planned to be installed over the decade is already under construction. In any case new hydro capacity should remain predominant at the margin, only less overwhelmingly so. Second, the CO_2 emissions of the profile of the most likely fuels [8] for increased consumption in an alternative scenario are on balance low. Natural gas in high efficiency combined cycle or STIG (Steam Injected Gas Turbines) central stations results in almost 60% lower emissions (at 45% efficiency, 110 kg C/MWh versus 295 kg C/MWh in typical coal-fired plants). Co-generation in the sugarcane industry results in no net emissions and may be an essential component of a strategy to maintain alcohol as a dynamic alternative to fossil fuel use in transport - reducing carbon emissions. Finally, the use of the heaviest residues of more intensive petroleum refining may contribute much less in practice than the nominal emissions of the power plant. Consumption of these sub-products does not drive petroleum demand. They must be burned somewhere (if not pumped back into suitable strata) and due to their typically high concentration of toxic elements (sulfur, vanadiun, etc.) power stations may be the best place to use them [7]. The impact of these potential changes might increase the direct CO_2 emissions per MWh generated from 9 kg C/MWh to a maximum of 22-24 kg C/MWh, still very low by World standards.

Electricity supply profile change

Presently in Brazil 1/3 of the total energy consumed is electricity of which 96% is from hydro origin[3]. From the environmental point of view, at a global level, hydroelectricity is classified as "clean" energy even considering the minor pollutant effects caused by emission of some level of GHG. Nevertheless the tendency for the year 2000 is to increase the percentage participation of thermoelectricity for the reasons cited above.

We are working in this paper assuming that the electric supply expansion over this decade will be based on the following expansion profile:

80% hydroelectricity
20% thermoelectricity
  - 10% from coal
  - 40% from natural gas
  - 30% from fuel oil & refinery residues
  - 20% from biomass

This has the effect of changing the electricity supply market in the year 2000 in such a way that only 90% will be due to hydro and the remaining from thermo.

Such an electric system will produce increased CO_2 emissions and to evaluate the amount we are assuming:

a) biomass will not add net CO_2 to the atmosphere since we are supposing that it will mostly be produced in the existing sugar and ethanol mills, burning sugarcane bagasse, produced from continuous sugarcane plantation;

b) fuel oil has an emission rate of 72.6 t of CO_2 per 10^{12} J of burned fuel;

c) natural gas has an emission rate of 50.6 t of CO_2 per 10^{12} J of burned fuel;

d) coal has an emission rate of 100 t of CO_2 per 10^{12} J of burned fuel;

e) hydroelectricity does not produce CO_2 emissions.

With these hypotheses, to generate 1 TWh we will produce 0.0372 Mt of C.

To evaluate the net cost of reducing CO_2 emissions via the improvements in energy efficiency addressed in the next item the marginal cost of expansion of the electrical systems is estimated to be on average $70/MWh. This is close to the average tariff level recommended in official financial plans for the sector. This avoided cost represents a benefit of conservation policy independent of CO_2 emissions.

Electricity demand

Residential Sector

The residential sector consumes about 22% of total electricity and contributes 30-37% of the electricity evening peak. Fuelwood energy accounts for a declining (but still important) contribution of the sector's energy requirements. About 40% of total demand is supplied through fuelwood. We have considered a range of technical options that could be implemented in this sector in wide scale up to year 2000. The discount rates used are of 12%/year. We consider particularly important the efforts to reduce electricity consumption and also the replacement of fuelwood by a more efficient energy source: LPG. We also consider that 20% of the household sector's fuelwood use gives a net contribution of CO_2.

Lighting

The current stock of residential lamps in Brazil amounts to 220 million of the incandescent type and about 8 million of the fluorescent type. Compact fluorescents and more efficient versions of incandescents and fluorescents are already manufactured in the country. We have considered that the incandescent stock would increase at a 3 percent annual rate up to the year 2000. This is lower than the historical average, but takes into account a baseline trend of higher participation of these lamp types in the market. We have then assumed that each year all these incandescent are being gradually replaced by more efficient types, fluorescents and compact fluorescent lamps - so in the year 2000 the incandescent lamp stock would be replaced by 50%, 30% and 20% of the above mentioned types, respectively. Replacing one incandescent of 60 W for a more efficient version (54W) yields at the generation point an economy of 7 kWh/year, and for a compact fluorescent an economy of 52 kWh/year at the generation point (for details of these calculations see Ref. [9,10]). These savings in electricity consumption correspond respectively to 0.26 kg C/year, 1.56 kg C/year and 1.93 kg C/year for each of the mentioned technology substitution, assuming a 90% hydro and 10% thermal based power generation up to year 2000. A very direct synergism of C avoidance with the use of improved energy efficient equipments is electricity saving. Including the value of electricity saved, cost of C avoided is negative as shown in the last column of Table 7.*

Implementation of these measures would represent total cumulative saving of 2.33 Mt of C in generation. Total annual costs of these measures are 1271 million dollars (1990 US$), or 545.49 US$/tC.

Water Heating

Seventy-five percent of the country's electrified households (26.3 millions as of 1987) have electric showers. This is the cheapest way to provide, for the average population, requirements of domestic hot water. We have estimated an existing stock of 24 million electric showers in 1990 and an annual growth rate of 2.1% during 1990-2000 (similar to the population growth rate). If we promote a wide penetration of solar water heaters in the domestic sector up to 50% in year 2000 this would avoid a total of 3.3 Mt.C and would cost 3.71 billion dollars.

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* The cost of avoided Carbon emissions was estimated from the consumer perspective, i.e. assuming the potential cost/benefit of a given technology substituion or measure taken. The consumer's cost and the benefit will depend on the price of the fuel/electricity considered and the costs of the new technology. In this paper it was assumed that consumers use a social discount rate of 12% to evaluate their investment decisions. The equation below summarizes the procedure used to evaluate the cost of avoided Carbon (CAC):

$$CAC = \frac{E + I1 - I2 \text{ (US\$)}}{\text{avoided annual C emissions (kg)}}$$

where E= value of annually saved energy expenses: I1= avoided annual investment cost of technology 1 (old) and I2=annual investments costs of technology 2 (new).

Here we have considered that a solar heater system would consume annually 100 kWh (to account for days of poor lighting), a capital cost of US$ 500, lifetime of 15 years, and annual operating costs of US$ 9. The conventional electric shower costs US$ 10, has a lifetime of 15 years, and annual operating costs of US$ 45. One advantage of C avoidance - electricity saved value - is already included in the figure presented in the last column of Table 7.

Refrigeration

The use of electricity in refrigerators represents approximately 33% of the total residential electricity consumption, and it is well known in Brazil that specific electricity consumption of refrigerators is quite high [11,12]. We have assumed here that a 20% reduction in electricity consumption for this end-use could be achieved with an investment of 40% of the regular model cost. For an existing stock of 27 million units, annual growth rate of 2% and a target of reaching year 2000 with 50% of the stock represented by the most efficient model, we avoid a total of 1.28 Mt of C emission. The electricity saved value is also included in the figure presented in Table 7.

Air-Conditioning

We are assuming that a total number of 2.848 million air-conditioners will be in use in residences in the year 2000. Average electricity consumption for the conventional model is 860 kWh/year and for the more efficient units 688 kWh/year [12]. This saving in energy will cost US$ 60.00 per unit with a total investment of US$ 136.6 million, since 80% of them will be installed after 1990 and all the new ones are of the energy saving type. Estimated average life for these equipments is assumed as 12 years. Total amount of C avoided is 0.203 Mt. Table 7 data also includes value of electricity saved.

Commercial and Services Sector

Total energy consumption of these two sectors increased threefold during the past 15 years. More than 90% of the energy consumed is electricity. Here we also consider many opportunities to increase the efficiency in the use of electricity. The discount rate is 12%, and electricity generation is assumed to be 90% hydro in the year 2000.

Lighting

In 1990 we estimate a total of 26 million incandescent lamps and 48 million fluorescent lamp in use in this sector [10]. Assuming a 2% growth rate in the incandescent market and 3% for the fluorescent (taken as 40W lamps), in the year 2000 the existing stock would be 32 million and 65 million respectively. Also, if we promote a gradual substitution so that in the year 2000 all the incandescents would be replaced by 20% of the krypton filled bulbs (more efficient), 45% of the fluorescents of the standard type, and 35% for compact fluorescents, the total avoided carbon emissions would amount to 0.369 Mt at a total cost of 210.6 million dollars (570.7 US$/t C).

Replacing all fluorescents of 40 W (magnetic ballast) by the 32 W version using electronic ballast would lead to a total accumulated saving of 0.27 Mt of C and at a total cost of 195 million dollars (722.2 US$/t C).

In Table 8 we also present the total avoided cost including electricity savings.

The Industrial Sector

Total electricity demand for this sector in the year 2000 was calculated assuming an average industrial economic growth of 3.5% per year and the same energy intensity of 1988. Electricity consumption was then analyzed for the major sectors and technological improvements were taken into account. (This is in agreement with the high growth alternative scenario described earlier).

Housekeeping Measures

From many evaluations performed by electric utilities [13,14] it is clear that a reduction of 10% in electricity demand can be achieved with better end-use management efforts. These measures should include a better choice of electric motors (avoiding oversizing which is very frequent), appropriate design of the internal distribution electric network, installation of small size transformer in parallel with the large one (which should be used during idle periods of the factory), correction on the load factor, avoidance of short term peak demand, better mechanical coupling between electric engines and the equipments driven by them, etc.

The adoption of such measures will provide a total saving of 8.6 TWh at year 2000, which is equivalent to avoiding the release 0.32 Mt of C to the atmosphere even in an electric system strongly based on hydropower (we are assuming that only 10% of the total electricity is generated from thermal sources).

The total costs incurred for these modifications should reach US$ 1 billion but the investments are cost-effective since only retrofits with pay-back time of 2 years or less are proposed. To determine the avoided cost of CO_2 reduction it is necessary to assume a lifetime for the investment. With 15 years of lifetime total reduction of CO_2 emission reaches 4.8 MtC at a cost of US$ 208.4/tC

Lighting

We have estimated that the existing stock of fluorescents of the 40 W size is 14 million. The cost of avoiding carbon emission by replacing these lamps (and ballasts) with the 32 W version is 0.75 US$/kg C, and each replacement would save annually 1.00kg of C. If by year 2000 all of the existing 40 W have been replaced, this would provide a total of 0.14 Mt of avoided C at a total cost of 7.6 million dollars.

High Efficiency Electric Motors

High efficiency motors are available in the national and international markets. The improvement in efficiency is a function of the motor size, being larger for smaller sizes (up to 10 HP) and decreasing to gains of 3% for motors with

100 HP. Considering this factor and the low efficiency of most motors in use in the country an average improvement of 7% can be expected [12].

Assuming that 60% of the motors will be replaced by high efficiency models up to year 2000, 3.1 TWh can be saved in that year yielding a decrease of 0.115 Mt on the amount of C emission. Total cost of the retrofit should be US$ 335 millions. Since useful life is 15 years the cost of C avoidance is US$ 193.7/tC.

Variable Speed Electric Motors

Modern technology allows the operation of AC motors (which are more reliable than DC) at speeds other than the one imposed by the grid frequency and the motor design. With variable speed it is possible to run a motor in partial load without decrease on its energy efficiency and to perform the same end-use with less energy consumption. Such technology is more useful in motors which drive variable loads and as such we assume that they will be used in 30% of the total motor market (measured in kWh/year). Up to the year 2000 half of this potential market can be occupied.

The average cost is US$ 450.00/HP, requiring a total investment of US$ 266 millions [12]. Electricity saved will represent less 0.124 Mt of C in the atmosphere in the year 2000. For an assumed useful life of 20 years the avoided cost is US$ 107.3/t of C.

Electric Ovens

According to [12] it is possible to save 10% of the electricity being consumed in electric ovens and electric boilers recycling the available heat surplus or installing more efficient equipment.

The expected retrofit rate is low but nevertheless 1/3 of the potential saving should be accomplished by the year 2000. The necessary investment to accomplish this savings may be estimated to amount US$ 178.3 million using the typical "pay-back" period of 1.5 years and the industrial energy cost of US$ 0.058/kWh, provided by Geller [12]. For a useful life of 15 years, total avoidance of CO_2 emission will reach 1.30 MtC at a cost of US$ 137.2/tC.

Electrolytic Processes

Studies carried on electricity intensive industries [16] showed that it is possible to reduce by 7% electricity consumption in metallurgical industries and 10% in chemical industries through improvements in electrolytic processes. An expected saving of 2.0 TWh of electricity should be possible by year 2000, yielding a reduction in C emissions of 0.074 Mt/year.

Total investments in retrofits add up to US$ 250 million and the useful life should be 15 years. As a consequence 1.12 Mt of CO_2 will be abated from atmosphere at a cost of US$ 223.2t of C.

In Table 9 we also include the value of electricity saved - last column, total US$/avoided t of C, provides the total avoidance costs.

Public Illumination

For this sector we have assumed that the existing stock of incandescent bulbs that are still in use in the country (a total of 1 million lamps) would be replaced by mercury vapour lamps (80%) and high pressure sodium lamps (20%). By the year 2000 this would represent an accumulated saving of 0.015 Mt C at a total cost of 80 million US$.- that is US$ 1600/t of C. Considering the value of electricity saved during the operational lifetime (12000 hours) the final cost is US$ 680/t of C.

Transport

Conditioning factors

Transport occupies a key place in the problem of minimizing carbon emissions. It is not only a large source of emissions but one whose share is tending to grow. Furthermore it is the most difficult sector in which to achieve substitution.

In Brazil transport is responsible today for 32% of carbon emissions, of which 82% are from road transport.

Carbon emissions from transport are a result of three broad factors:

- the demand for transport services in different markets such as passenger (urban, rural and interurban) and freight (local and interurban) and different modes that serve these markets;
- the efficiency with which different energy forms are used in different modes and markets;

- the carbon emission coefficient of the energy form used.

Policy can act on all these factors.

Fuel substitution

The confirmation of carbon emissions as a serious problem will have enormous consequences for long term substitution policy for transport. In most countries this is a question whose effects will be felt only after the year 2000. However in Brazil, which has emphasized fuel substitution in its energy policy more than almost all other countries, the consequences are more immediate. The most important example is the fuel alcohol program for private automobiles.

Alcohol

Brazil's alcohol program is unique. It is one of only two large scale efforts to substitute petroleum derivatives among common transport fuel consumers (compressed natural gas substitution is more widespread but also targets specialized consumers). The other effort, South Africa's SASOL coal - liquid fuel conversion technology, is more in tone with what has been the "mainstream" world long-term search for non-petroleum alternatives for transport fuel. In common with these mainstream alternatives SASOL involves significantly increased carbon emissions per GJ of fuel supplied (Table 10) relative to petroleum. In contrast, Brazil's alcohol program involves near zero emissions, especially with the criteria used to evaluate these technologies. Brazil's alcohol program represents by far the most significant attempt in the world energy sector to reduce the carbon emission of transport fuel supply, even though this was not initially an explicit objective of the program. Curiously, just as the carbon-emission problem is becoming a key world energy policy concern, the alcohol program is in deep crisis in Brazil, and could well suffer contraction over this decade, as suggested by a World Bank energy sector analysis concluded in 1990 [16].

Alcohol requires subsidies to compete with gasoline, especially after the 1986 collapse of crude oil prices. The macro-economic situation of the country is more favorable to the expansion or even maintenance of the existing subsidy level. Major productivity gains in alcohol production are possible, including especially the exploitation of sugarcane residues and sub-products, which can reduce costs. A historic tendency in this sense already exists. However these improvements in competitivity will take time to significantly reduce industry-average costs. As such this decade is unlikely to see significant expansion of alcohol production. The most important issues in this time-frame are whether alcohol will be reduced, and whether qualitative changes can occur in the industry which can position it for more vigorous growth in the next decade.

Reflecting this possibility an increase of only 2 million tons of oil equivalent (from a 1990 level of 5.6 million Toe) is compared with stagnation. This results in a reduction of 1.6 million t of C per year, with a subsidy (assuming gradual improvements in the average cost of alcohol production to US$ 0.28 per litre) of 12 cents per litre of gasoline substituted, or US$ 193 per t of C. The lifetime of the impact of this subsidy flow has no simple defining criteria. A policy allowing modest growth may accelerate the incorporation of productivity improvement throughout the industry and investment with longer term impact will increase. This would increase the attributable reduction of CO_2 and reduce the cost per t of C. The difference between stagnation and optimistic scenarios should grow after 2000, with significantly lower costs per t of C as new technologies (such as gas turbine co-generation) are more widely incorporated.

Highway system recovery

A significant share of the total cargo transportation (60%) is performed by roadways using diesel powered trucks. According to Ketoff [17], 64% of the diesel consumed in transport is due to intercity and interstate freight.

In 1990 total diesel consumption reached 15.5 Mtoe in the transport sector, and 9.9 Mtoe was used by trucks on highways. Total energy consumed in this same year for transportation reached 32.8 Mtoe - that is 30.2% of total consumption occurred for the end-use we are discussing. Assuming the same proportion will remain in the year 2000, intercity load freight will require 15 Mtoe of diesel fuel.

A study performed by the Ministry of Transportation [18] concluded that high quality paved roads can save as much as 40% fuel as compared with poorly kept paved ones. For a preliminary calculation we are assuming that 20% of fuel economy could be obtained in the year 2000, since only half of the 130,000 km of highways requires intense recovery work and this action could be completed in the coming 9 years.

The CO_2 emission coefficients for the average truck fleet is 70 t of CO_2 per TJ of fuel energy and the highway recovery cost is US$ 200,000/km [19]. With these figures it is possible to calculate that emission of 0.88 Mt of C per year could be avoided with an investment in highway recovery of US$ 13 billion. The useful life for the highway recuperation is 5 years [19] which means that total C abatement will reach 4.4Mt. at a cost of US$ 2142/tC, when the cost of fuel saved is also taken into account. Other economic benefits result as well. While it is not possible to estimate these, the net cost per t of C could be very substantially reduced.

Efficient diesel engines

Another possibility for CO_2 emission reduction in the transport sector on highways is the use of a new generation of diesel engines which are more efficient than the traditional ones. Such improvement should be extended to intercity public transportation. By the year 2000 approximately 1.76 million diesel powered buses and trucks should be in operation (we assume that total fleet will grow at 4%/year - which was the average growth rate in the 81/85 period). 20% of these motors can be of the new generation with a total diesel economy of 1 Mtoe, since these motors are 20% less energy intensive than the conventional ones [20]. The cost of such engines represents an extra investment of US$ 5000/unit. Thus we achieve an annual reduction on C emission of 0.9 Mt at a cost of US$ 1.76 billion. Since the useful life for the engine is 3 years total avoidance of C is 2.7 Mt at a cost of US$ 672/t of C including the value of diesel saved.

Vehicle efficiency

Increased efficiency of automobiles can bring significant reductions in emissions. Some improvements in fuel efficiency of new cars, are occurring and can be expected to occur. A range of measures, capable of increasing individual new car efficiency to 14.7 kg/litre and costing less than 0.26 per litre of gasoline saved (using a 12% discount rate), was considered [21]. The dynamics of market penetration of individual measures and of the fleet renewal rate were conservatively estimated to limit the increase in efficiency to about 25% for the entire automobile fleet. Assuming a fleet 50% larger in the year 2000 than in 1990 similar annual trip kilometers per vehicle, and all savings from gasoline, roughly 3.2 million t C per year could be saved. (Alcohol consumption is held constant to be consistent with assumptions elsewhere regarding that fuel). Lifetime attributable savings can be crudely estimated to be at a minimum ten times the annual savings, or 32 million t. The average cost of these measures is estimated to be US$0.17 per litre of gasoline. Since gasoline distributed cost is taken to be $0.26 per litre, the cost is negative $0.09 per litre or $150 (negative) per t of C.

Improved urban transportation

As is well known urban transportation made by bus in normal traffic lanes can transport 6,000 to 10,000 passengers per hour. To increase this flux, cities with high population density installed subway systems, which are able to carry as many as 70,000 passengers/hour per track. Subway systems are quite expensive. In the city of Sao Paulo recent investments in a new line cost more than 100 million dollars per km.

An intermediate solution is the construction of private lanes for bus circulation. Under these lanes it is possible to carry 20,000 passengers per hour with increased speed of the buses. A recent experience in the city of Sao Paulo has shown that average bus speed has increased from 13-15 to 21 km/hour in a special corridor built at an average cost of US$ 2 million/km including all passenger loading and unloading infrastructure [22]. According to a study carried by the Bus System Authority of Sao Paulo [23] this yields an economy of 0.1 litre/km. Assuming a total flux of 2000 buses per day on an express lane 16 km long, a total of 3200 litres of diesel oil is saved per day.

Assuming an average life of 20 years for the lane it is possible to conclude that 16,777 t of C will be saved with the total investment of US$ 32 million that is US$ 2147/t of C saved.

Many other synergistic factors should be computed as a consequence of the investment. To be coherent with our previous calculation we will only add the total economy derived from the amount of oil which was saved. The total amount per year yields US$ 250,000 which has a present value of US$ 2,100,000, bringing the cost of C avoidance down to US$ 2000/t of C. A more important synergistic factor is the overall increase in productivity of the bus system. It is such that the net economic cost may be zero, especially if complementary measures such as integration are undertaken [24]. The most significant CO_2 emissions reduction will result from the longer term impact on automobile usage due to improved collective transport. A worthwhile estimate of the possible dimension of this impact will require additional study.

Considering a widespread acceptance of this technology, we assume that 20 of these corridors could be in operation in several cities in the year 2000, providing an annual saving of 0.017 Mt of C.

Table 11 summarizes the main results for the transport sector

Changing land-use trends

By far the largest source of anthropogenic carbon emissions in Brazil is the result of deforestation, principally in Amazonia. It accounts for about 80% of total emissions. Unlike many developing countries deforestation is not strongly related to the energy use of fuelwood. It is primarily a result of grazing, agricultural and logging activities. Since this case study concentrates on energy, no detailed attention could be given to these activities, the subject of much polemic and a rapidly growing literature. On the other hand, the relative magnitude of their impacts and the complex, often subtle inter-relations with energy-related activities, demands at least brief attention as to how policy might influence deforestation. The consequences of such policies will be very important for electricity generation and industrial charcoal.

The regional economy of much of Amazonia, especially along the agricultural frontier, is today strongly dependent on and adapted to the deforestation process. As such any strategy to achieve a large sustainable decrease in the deforestation rate must go beyond the police enforcement of forest land-use legislation to create a new economy dynamically less predatory in its use of forest, land and water resources. Some of this can be achieved simply by reducing or eliminating the legal and financial incentives to deforestation which exist [25]. At the same time it is necessary that alternative or modified economic activities be developed and strengthened both in deforested and forested areas.[26] Zoning of land-use is broadly recognized as fundamental, and should be reflected in norms, incentives and infrastructure investment.

In the largely deforested areas along the frontier and the "pre-frontier" there is a need to stabilize, consolidate and (in many areas) intensify settlement and economic activity. The options vary among regions but include:

- stabilization and recuperation of pasture;[27]
- conversion of some pasture to agriculture where land-use capability permits;[26]
- reforestation of some degraded pasture to produce commercial products (eg. pulp, metallurgical charcoal);
- stimulate natural forest regeneration in some degraded pasture; [28]
- economic infrastructure (eg. transport and electricity) to reduce costs of inputs and decrease price of products;
- social infrastructure (eg. health and education).

The articulation of such a strategy poses large institutional challenges. Development of technologies and scientific understanding is a continuing need. Public sector resources will be required whether for investment in infrastructure, operation of programs, credit or specific incentives. No consolidated estimate exists as to what the costs of such a strategy would be. However, an illustrative calculation suggests that even a rather massively funded program could result in relatively low cost carbon savings. At, for example, the equivalent of about US$ 4 per barrel of oil saved or US$ 35 ton of carbon, roughly $ 2 billion per year might be available for "catalytic" expenditures. By 2000, in principle, savings of the order of a billion tons of carbon might be attributable.

Such a strategy to reconcile development and environmental goals may be beyond the institutional capability and will of the government today. However the possibility of large relatively low cost carbon savings urges a systematic evaluation of this strategy.

It should be observed that reforestation with conventional relatively homogeneous plantations to sequester carbon in biomass stocks, sometimes emphasized, may be only a relatively small part of the reduction of net carbon emissions. The nearer term emphasis is on decreasing deforestation rates, while increase in biomass stocks on formerly deforested land may be due as much or more to regeneration of natural forest. Conventional plantations are relatively expensive to establish and may only be economically justifiable if they produce commercial products. A key energy issue in this context is whether plantations for charcoal metallurgy can replace the current preponderance of charcoal from cleared native forest.

Electricity generation policy may also be influenced by a regional strategy to minimize deforestation [7]. The relative priority of hydro projects in different zones may be altered; some projects may become unviable; the rhythm of exploitation of Amazonia's hydro potential may be reduced. While direct carbon emissions may increase somewhat (from a very low base) for electricity generation, these may be more than compensated by the contribution to an overall strategy to reduce deforestation.

Conclusions

Figure 1 summarizes the estimates made in this work. These estimates are quite approximate and do not represent a complete selection of possible measures to reduce CO_2 emission. Nevertheless several broad conclusions can be drawn. First significant reductions can be achieved at a "negative" economic cost with diverse energy conservation measures. This is a consequence of the well known fact that much conservation is at a lower cost than energy supply. CO_2 reduction simply becomes another reason to stimulate conservation. Some conservation/CO_2 reduction measures appeared to be quite expensive, such as highway recuperation (metros would be another example). In some of these cases, however a more thorough examination of all the costs and benefits associated with a measure may drastically reduce the net cost attributed to CO_2 reduction. This may be especially so in the important area of transportation. For example, highway recuperation or collective transport improvement clearly brings benefits beyond CO_2 reduction and energy conservation. These other economic or social benefits may be far larger in some cases, though they were not included in these still highly simplified calculations. The same can be said for the measures and investments to reduce deforestation. While the cost of a program as estimated here is quite modest per t of carbon, its net cost may be substantially lower if other economic and social benefits are taken into account.

Some CO_2 reduction via fuel substitution (eg. natural gas) has little or no net cost. A major exception is transport fuel substitution. Transport "synfuels", except alcohol actually increase CO_2 emissions. This advantage of alcohol is balanced by its relatively high cost, which will inhibit growth during this decade. However improvements in the alcohol production process, together with rising oil prices should make the net cost per t of carbon quite modest by the next decade.

TABLE 1

TOTAL ENERGY USE IN BRAZIL - 1990 in Mtoe

Sector	Oil	Hydro	Firewood	Alcohol	Other	Total
Energy Generation	2.0	2.0	-	-	9.3	13.3
Residential	5.3	13.8	7.9	-	0.6	27.6
Commer/Public	0.7	12.0	0.1	-	-	12.9
Agro-forestry	3.2	1.8	2.1	-	-	7.1
Transportation	26.8	0.3	-	5.6	-	32.8
Industrial	8.0	32.8	4.9	-	19.2	65.0
Total	46.1	62.8	15.0	5.6	29.2	158.7

Source - Balanco Energetico Nacional - Secretaria Nacional de Energia - Ministerio da Infraestrutura, Brasilia, Brazil

TABLE 2

SOCIO & ECONOMICAL DATA - BRAZIL 1990, 2000 AND 2010

	Units	1990	2000	2010
Population	millions	150.4	183.3	223.5
GNP	billions of US$	289.4	423.6	690.0
GNP per capita	US$/inhab	1924.3	2310.5	3087.4
Final Energy	10*6toe	158.7	240.3	354.7

Source : Reexame da Matriz Energetica Nacional, Secretaria Nacional de Energia, Ministerio da Infraestrutura Brasilia, Brazil, 1991

TABLE 3

AVERAGE RATE OF ECONOMIC GROWTH (%)

Year	Hypothesis Low Growth	High Growth
1990	-3.0	-3.0
1991	0.0	1.0
1992	1.0	3.0
1993	3.0	5.0
1994	5.0	5.5
1995 to 2010	5.0	6.0

Source - Ministerio da Economia, Fazenda e Planejamento, Brasilia, Brazil, 1990

TABLE 4

ENERGY SUPPLY PROFILE - HIGH ECONOMIC GROWTH ALTERNATIVE SCENARIO

	%			millions of toe		
Energy Source	1990	2000	2010	1990	2000	2010
Oil	30.0	30.0	30.5	55.1	79.4	118.1
Natural Gas	2.0	4.7	6.0	3.7	12.3	23.3
Coal	5.0	5.0	6.3	9.1	15.2	24.5
Nuclear	0.3	1.2	1.4	0.6	3.2	5.3
Other	0.0	0.4	0.2	0.0	0.9	0.9
Total (non-renewable)	37.3	42.3	44.4	68.5	111.0	172.1
Hydro	36.9	32.8	32.8	67.8	86.4	126.5
Alcohol/Sugarcane	9.9	10.0	10.0	18.1	26.3	38.5
Firewood	14.9	13.5	11.4	27.4	35.5	44.1
Other	1.0	1.4	1.4	1.8	3.7	5.4
Total (renewable)	62.7	57.7	55.6	115.1	151.9	214.4
Total	100.0	100.0	100.0	183.6	262.9	386.6

Source: Reexame de Matriz Energetica Nacional, Ministerio da Infraestrutura, Brasilia, Brazil, 1991

TABLE 5

FINAL ENERGY DEMAND - HIGH ECONOMIC GROWTH ALTERNATIVE SCENARIO

	%			millions of toe		
	1990	2000	2010 -	1990	2000	2010
Electricity	37.2	38.7	39.5	62.8	93.0	140.3
Oil Derivatives	32.7	31.9	32.8	55.2	76.6	116.7
Firewood & Charcoal	12.4	10.8	8.7	20.9	26.0	30.7
Alcohol and Bagasse	10.4	8.9	8.5	17.5	21.3	30.3
Natural Gas	1.9	3.9	5.2	3.2	9.4	18.4
Coke and Coal	3.5	3.6	3.3	5.9	8.6	11.6
Other fuels	1.9	2.2	2.0	3.2	5.4	7.2
TOTAL	100.0	100.0	100.0	168.7	240.3	354.7

Source : Reexame de Matriz Energetica Nacional, Ministerio da Infraestrutura , Brasilia. Brazil, 1991

TABLE 6

ENERGY CONSUMPTION IN SEVERAL SECTORS OF THE ECONOMY

(millions of toe)

Sector	2000	2010
Energy Generation	20.2	29.8
Residential	41.8	61.7
Commercial/Public	19.5	28.8
Agro-forestry	10.8	16.0
Transport	49.6	73.2
Industrial	98.4	145.2

Source - Reexame da Matriz Energetica Nacional, Ministerio da Infraestrutura, Brasilia, Brazil, 1991

TABLE 7 RESIDENTIAL SECTOR TECHNOLOGIES TO LIMIT CO_2 IMPLEMENTABLE BY YEAR 2000

	(1) old technology	(2) new technology	(3) avoided kg of C / unit/year	(4) US$ / avoided kg C	(5) value of saved eletricity US$/kg C	(6) = (4) - (5) total US$ / avoided kg C
	incand. std	eff. incand	0.260	0.192	1.989	-1.797
lifetime (h)	1000	1000				
power (W)	60	54				
usage (h/y/lamp)	1000	1000				
	incand. std	fluor. std	1.562	0.338	1.135	-0.797
lifetime (h)	1000	8000				
power (W)	60	24				
usage (h/y/lamp)	1000	1000				
	incand. std	compact. fluor.	1.934	0.9189	1.135	-0.216
lifetime (h)	1000	8000				
power (W)	60	16				
usage (h/y/lamp)	1000	1000				
	electric shower	solar	14.88	1.1263	0.879	+0.2473
lifetime (y)	15	15				
usage (kWh/y)	500	100				
	refrigerator std	eff. refrigerator	5.208	1.024	0.879	+0.1457
lifetime (y)	15	15				
consumption (kWh/y)	600	480				
	air conditioner std	air condit. eff.	7.44	0.672	0.984	-0.312
lifetime (y)	12	12				
consumption (kWh/y)	860	688				

TABLE 8 COMMERCIAL & PUBLIC SECTORS TECHNOLOGIES IMPLEMENTABLE BY YEAR 2000 TO LIMIT CO2

	(1) old technology	(2) new technology	(3) avoided kg C / unit/year	(4) US$ /avoided kg C	(5) Value of Saved elect/kg C	(6)=(4)-(5) Total US$ avoided/kg of C
	incand.std	incand. eff.	0.789	0.243	2.688	-2.445
lifetime (h)	1000	1000				
power (W)	100	90				
usage (h/y/lamp)	1920	1920				
	incand. std	fluoresc.std	4.285	0.249	2.688	-2.439
lifetime	1000	8000				
power (W)	100	48				
usage (h/y/lamp)	1920	1920				
	incand. std	compact fluor	2.280	0.843	2.688	-1.840
lifetime (h)	1000	8000				
power (W)	60	16				
usage (h/y/lamp)	1200	1200				
	fluor. std	fluor. eff.	1.000	0.750	2.690	-1.940
lifetime	8000	8000				
power (W)	48	36				
usage (h/y/lamp)	1920	1920				
	incand. std	mercury/sodium	15.27	1.600	1.392	0.208
lifetime (h)	1000	12000				
power (w)	175	80 and 70				
usage (h/y/lamp)	3650	3650				

TABLE 9

INDUSTRIAL SECTOR TECHNOLOGIES IMPLEMENTABLE BY YEAR 2000 TO LIMIT CO_2 EMISSIONS

Sector	(1) Avoided MtC/year	(2) US$ avoided/tC	(3) Value of saved electricity/tC	(4)=(3)-(2) Total US$/ Avoided tC
Housekeeping Measures	0.32	208.4	689.0	-480.6
Lighting	0.14	750.0	1560	-810
High Efficiency Motors	0.115	192.9	689.1	-496.1
Variable Speed Drivers	0.124	107.3	575.7	-468.4
Electric Ovens	0.087	136.7	687.9	-551.2
Electrolytic Processes	0.074	605.2	692.6	-467.4

TABLE 10

CARBON DIOXIDE EMISSION RATES FOR CONVENTIONAL AND SYNTHETIC FOSSIL FUELS

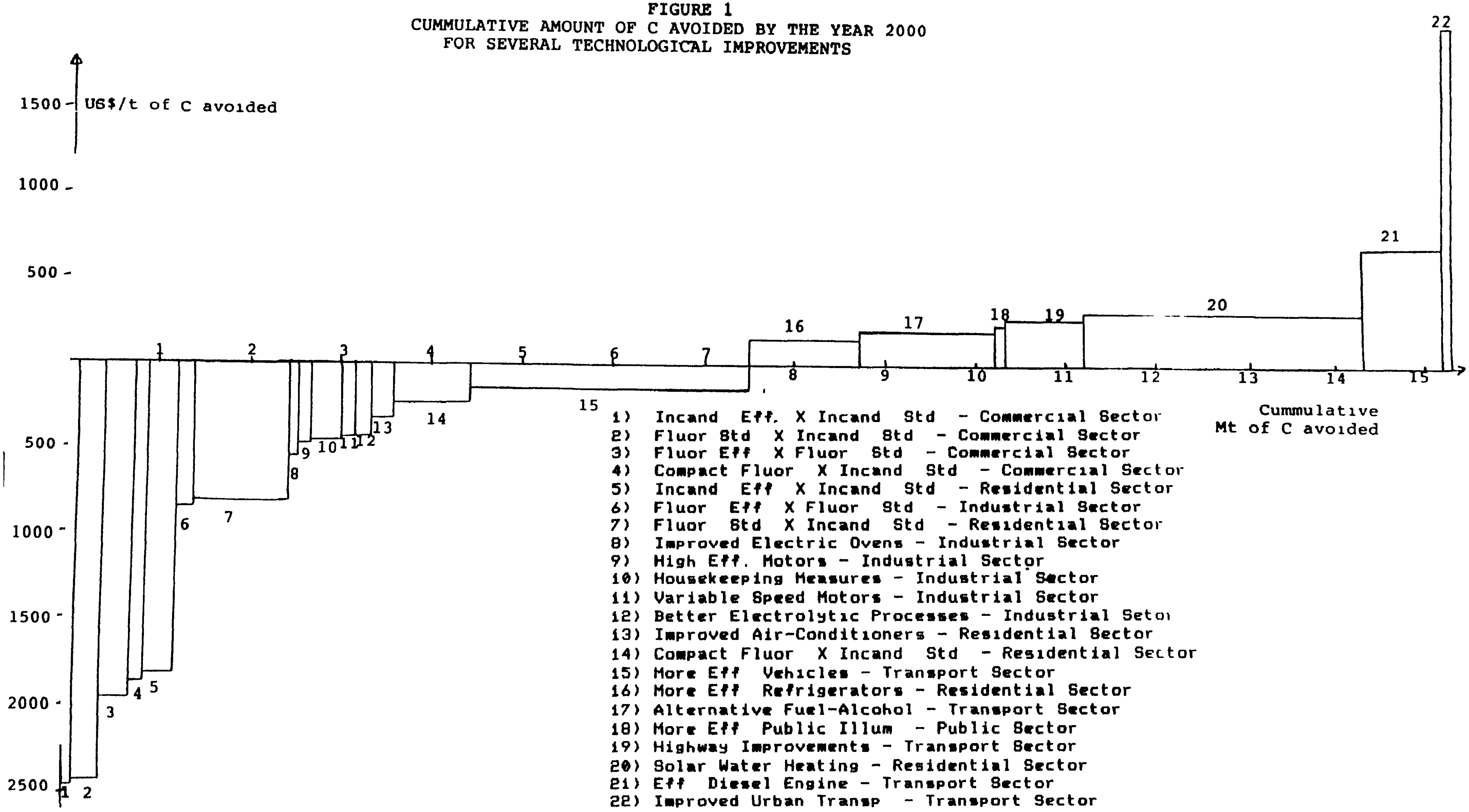
FUEL	CO_2 EMISSION RATE (KG C/GJ)	NOTES
CONVENTIONAL FOSSIL FUEL		
Natural Gas	13.5 - 14.2	
Liquid Fuels from Crude Oil	18.2 - 20.6	
Bituminous Coal	23.7 - 23.9	
SYNTHETIC FUELS		
Shale Oil	66.4	High temperature retort 25 gal/t of shale
	47.6	Modified in situ, 28 gal/t of shale
	28.4	Low temperature retorting
Liquids from Coal	41.8	Sasol-type technology
	38.6	Exxon-Donor Solvent
	31.9	Gerenic-79% efficiency
High-Btu Gas from Coal	40.7	Lurgi

TABLE 11

TRANSPORT SECTOR TECHNOLOGIES IMPLEMENTABLE BY THE YEAR 2000 TO LIMIT CO_2 EMISSIONS

Source of Reduction	Avoided MtC/year	US$/avoided tC
Fuel substitution(alcohol)	1.6	193
Highway Systems Recovery	0.88	2142
Efficient Diesel Engines	0.9	672.2
Increased Automobile Efficiency	3.2	-150
Improved Urban Transportation	0.017	2000

FIGURE 1
CUMMULATIVE AMOUNT OF C AVOIDED BY THE YEAR 2000
FOR SEVERAL TECHNOLOGICAL IMPROVEMENTS



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CHAPTER 4 : CHINA COUNTRY PAPER

Wu Zongxin, Wei Zhihong

Institute of Nuclear Energy Technology, Beijing, China.

Executive Summary

China is a developing country with a population of 115 million living on a territory of 9.6 million square kilometers. The GNP was 365 billion US$ in 1990 (at 1990 prices) and the per capita GNP was 317 US$ reflecting a comparative low economic level. China is also a large country in terms of energy production and consumption. In 1990, total primary commercial energy production reached 728 Mtoe and consumption 686 Mtoe, in which coal accounted for 75.6% as the predominant fuel. The per capita commercial energy consumption was at a lower position which was 0.6 Toe in 1990, about one third of the world' average. Apart from commercial energy, a large quantity of biomass energy is still consumed to satisfy the demand in rural areas. Biomass energy roughly made up 24% of total energy consumption nationwide and 75% of energy consumption in rural households.

Since the energy intensity of economy was 0.98 kgoe/US$ (at 1980 prices) in 1990 which was around 3.5 times that of the developed nations in early 1980s, so that there exists great rooms for energy conservation and then CO_2 reduction from the macro-economy point of view. To support the empirical view, this study paper intends to analyze more detailed where the potentials exist and how big they would be in terms of overviewing current situation and projecting scenarios in 2000 of energy consumption and CO_2 emission by fuelwise and sectorwise. And finally, the more important studies, i.e. cost of CO_2 saved or fixed by various technologies, are done according to the cost of capital investment, operation & maintenance, and fuels which are approximately estimated so far.

Improvement of energy utilization efficiency, replacement of carbon fuels by non-carbon fuels, afforestation are the major strategies which will be adopted in China to abate CO_2 emission.

Power generation sector which consuming 280-300 Mt of coal each year, industrial boilers and kilns which consuming 290-330 Mtoe of energy a year and households sector which needing 100 Mtoe of commercial energy supply a year are the biggest energy consumers in which potentials for energy efficiency improvement exist if new technologies or retrofitting measures are adopted. For example, power generation efficiency can be raised from current average level 30.7% to 37-38% by using advanced technologies of PFB or IGCC, heat efficiency of boilers and kilns from 55% to 65%, 25% to 30% respectively through technical innovation, urban cooking efficiency from 22% to 50% by gasification, and rural cooking efficiency from 10% to 20% by using coal-saving stoves. Since the absolute energy consumption are very big in these sectors and efficiency improvement will resulted in a large amount of energy saving, so more attention should be paid in the field.

Because of the quite higher cost of using renewable energy such as solar, wind, geothermal etc., hydropower and nuclear energy will be the major non-carbon fuels used in the near future. It is expected that hydropower capacity will develop from 40 GW in 1990 to 80 GW in 2000, which accounts for 20% of the total exploitable hydropower resources, and nuclear power will emerge from nothing now to 6 GW in 2000.

There is a bright prospect in afforestation, China will afforest 16-17% of its land area by the end of this century over the share of 13% in 1990. If the target could be realized, there would be 690 million ton of carbon to be assimilated and no CO_2 emission resulted from net deforestation.

The specific cost of reducing CO_2 emission for selected technologies and measures are calculated and listed in a table in a ascending order for comparison. It is known from the preliminary results that adoption of coal-saving stoves in rural households is of the lowest specific cost, that is why policy makers make a big plan to enable 90% of rural households using this kind of efficiency-improved stove in 2000 over 35% in 1990. And, generally speaking, innovation on existing equipments will have comparative lower specific cost. Finally, fairly reasonable specific cost of both hydropower and nuclear power make them to be competitive ones.

Introduction

China is a developing country with a population of 1143 million living on a territory of 9.6 million square kilometers. The Gross National Product was 1740 billion Yuan (running price) in 1990 and the GNP per capita is estimated to be 1522 Yuan which was equivalent to US$ 317 in terms of the exchange rate 1 US$ = 4.8 Yuan in 1990, reflecting a relatively low economic level.

China is a large country in terms of energy production and consumption. In 1990, the total primary energy production reached 728 Mtoe and the total energy consumption was 686 Mtoe. From 1980 to 1990, the average annual growth rate of both energy production and energy consumption were about 5.0% respectively. In 1990, China's raw coal production was 1080 Mt. crude oil production 138.1 Mt, natural gas production 15.2 billion cubic meter, and electricity generation reached 618 Twh. The energy consumption in 1990 was that raw coal 1037 Mt. crude oil 117 Mt, natural gas 15.2 cubic meter.

China's energy economy has been characterized by the following :

- Self-sufficiency in energy sources -- the entire economy is based on domestic energy resources.
- Coal is the predominant energy source -- in 1990 coal accounted for 75.6% of the primary energy consumption.
- Uneven geographical distribution of energy resources -- 80% of existing coal reserves are concentrated in North

China and Northwest, which are far from the industrial centers located in the eastern part of the country. Hydro resources are mainly concentrated in the Western part of the country.

* Hydropower resources have not been adequately exploited -- the exploitable hydropower resources in China is equal to 380 GW, but so far only 10.3% has been exploited.

* Initial stage for exploration of crude oil and natural gas resources -- so far the proven oil reserves account for only 17% of the total oil resources and the proven gas resources only 3.4% of total natural gas resources. In 1988, the available reserve/exploitation ratio of oil was 13.

* A lower per capita energy consumption, and higher energy consumption for unit output value (energy intensity) -- China's per capita commercial energy consumption in 1990 was 600 kgoe, about one third of the world's average, while the unit GNP energy consumption was 0.98 kgoe/US$ (1980 prices), among the highest ones in the world. in 1988, per capita electricity consumption in livelihood was 89 kwh for urban inhabitants and 17 kwh for rural ones.

* Higher dependency on biomass energy for domestic use by the rural population -- as roughly estimated, 75% of the energy for domestic use of China's 800 million rural inhabitants depend on biomass energy.

There exists great scope for modifying the energy consumption pattern in China. The energy intensity of the economy was 0.98 kgoe/US$ (1980 prices) in 1990 which is about 3.5 times that of the developed world in early 1980s. From 1980 to 1990, GNP grew at 8.9% p.a. and the rate of growth of energy consumption was 5.0%, so that the energy elasticity is 0.56.

Energy Consumption and CO_2 Emissions in China

According to formal statistics, commercial energy consumption of China in the past decade are shown in Table 1, 2 in terms of fuel mix and sectoral structure respectively. All kinds of fuels data are expressed in physical units. i.e., by weight or volume, but total energy consumption measured in a common unit of ton of oil equivalent (toe) are also listed after transferring various fuels into standard one based on the coefficients given in Table 3. Apart from commercial energy, biomass energy consumption is given at the same time which is roughly estimated. Stalks and straws, firewoods are the major types of biomass in China. The latest data for various fuel consumption in Table 1 can be obtained up to the year 1990, but it was just up to 1988 about sectoral energy consumption composition in Table 2, as adequate data were lacked for the past two years.

Table 1 Primary energy consumption in China

Items	Unit	1980	1985	1990
1. Commercial energy				
(1) Coal	MT	609	814	1037
(2) Oil	MT	88	92	117
(3) N.G.	Bm^3	14.1	12.7	15.5
(4) Hydropower	Twh	58.2	92.4	126
(5) Subtotal	Mtoe	422	537	686
2. Biomass energy				
(1) Stalk & straws	MT	240	253	254*
(2) Firewood	MT	198	193	300*
(3) Subtotal	Mtoe	160	163	206*
3. Total	Mtoe	582	700	

* Figures in 1987.

Table 2-1 Sectoral Composition of energy consumption in China in 1980

Sectors	Coal (MT)	Oil (MT)	N.G. ($M m^3$)	Elec. (Twh)	Bio. (MT)
1. Agriculture	15.5	8.2	--	27.0	--
2. Industry	316.5	43.2	13500	232.5	16
3. Power	126.5	20.8	240	19.4	--
4. Transportation	19.3	9.2	70	2.7	--
5. Household	115.7	1.4	200	10.5	422
6. Service/commerce	15.5	5.2	50	8.6	--
Total	609.0	88.0	14060	300.7	438

Table 2-2 Sectoral composition of energy consumption in China in 1988

Sectors	Coal (MT)	Oil (MT)	N.G. ($M m^3$)	Elec. (Twh)	Bio. (MT)
1. Agriculture	23.8	9.3	--	37.9	--
2. Industry	494.0	57.2	12080	406.2	30
3. Power	249.5	18.4	580	36.6	--
4. Transportation	22.6	15.6	110	9.0	--
5. Household	175.3	2.8	1530	34.3	524
6. Service/commerce	28.4	7.7	60	22.8	--
Total	993.6	111.0	14360	546.8	554

Table 3 Coefficients to standard fuel

	Fuel	Units	Calorific value (Kcal)	Transfer coefficients
1.	Standard fuel	Kgoe	10,000	1
2.	Coal	Kg	5,000	0.5
3.	Crude oil & oil products	Kg	10,000	1
4.	Natural gas	m^3	9.300	0.93
5.	Stalk & straws	Kg	3,400	0.34
6.	Firewood	Kg	4,000	0.40

Note : Electricity is transferred to standard fuel according to actual fuel consumption for generating per Kwh of electricity, e.g. it was about 0.277 Kgoe/Kwh in 1990.

The total commercial energy consumption of China in 1988 was 647 Mtoe. The sectoral structure in final energy consumption was as follows : industries consumed 67.8%, while the share of the agriculture, forestry, fishing, livestock farming, together was 5.3%. Residential consumption accounted for 17.4%, and the share of transportation was 4.8%; while commercial/service sector consumed 4.7%. The important feature of the energy situation is the dominance of industrial sector consumption. A large industrial sector has been built up over the past 40 years through high capital investment. This sector is the main consumer of each fossil energy type (50.8% for coal, 52.1% for crude oil and oil products), partly because of high energy intensities, though these have decreased significantly in recent years. If power generation is included in the industrial sector, the share of industries in total coal consumed increases to 73.9% and that in oil to 65.9%.

China is the world's largest coal producing and consuming country. In 1988, domestic coal consumption reached 994 Mt, among which 23.1% was for power generation, 17.3% for cooking & space heating, 50.8% for other industries, 2.2% for transport, and 3.0% commercial/service. China is also one of the few countries in the world which predominantly relies on coal as its main energy source. Of the total primary energy consumption in 1990, coal accounted for 75.6%, while oil 17.0%, natural gas 2.1%, and hydropower 5.3%.

Based on fossil fuel and biomass energy consumption, corresponding CO_2 emission can be derived accordingly by using the emission factors shown in Table 4 which are considered generally to be fairly suitable to the present situation in China. It should be noted that CO_2 emission factor of biomass mainly concerns the end-use device of firewood stove widely adopted in rural households. Since CO_2 emission from the combustion of agricultural residues could be thought as a carbon recycle balance, net deforestation should only be included in the emission from biomass. At present time, there exists very serious shortage of rural energy supply, only 100 million tons of firewoods can be supplied reasonably. However, the actual demand figure is accounted as 300 million tons, the another 200 million tons of shortage are balanced by overcutting, among which about 100 million m3 of forest resources are burnt every year and just equal to the deficit between consumption and growth of forest. Thus, an approximate estimate is made that one fourth of firewoods combustion in Table 1 is taken as the cause of net deforestation, and CO_2 emission from it should be calculated. In Table 5, current CO_2 emissions of China are listed according to fuelwise and sectorwise. As estimating CO_2 emission from fossil fuels, it is assumed that in coal consumption, about 3% is lost in transportation and distribution and 6% escapes through flue gas or remains in the gangue after burning, thus these portion of coal is treated not to release CO_2 ; in oil consumption, about 2% lost in transportation and distribution and 15% taken as raw materials for manufacturing petrochemical products such as ethylene, rubber and so on in which carbon is fixed; in N.G. consumption, 2% leaked away in transportation and distribution .

Table 4 CO_2 emission factors of fuels

	Fuels	emission factors
1.	Coal	1.05 (T-C/toe)
2.	Oil	0.78 (T-C/toe)
3.	N.G.	0.59 (T-C/toe)
4.	Firewood	0.30 (T-C/toe)

Table 5-1 CO_2 emission from fuels in China (million T-C)

		1980	1985	1990
1.	Coal	291	389	495
2.	Oil	57	60	76
3.	N.G.	8	7	8
4.	Firewood	6	6	9*
	Total	362	462	588

* Figures in 1987.

Table 5-2 CO_2 emission of sectors in China (million T-C)

		1980	1988
1.	Agriculture	14	18
2.	Industry	182	274
3.	Power	76	134
4.	Transportation	16	23
5.	Household	62	95
6.	Service/commerce	12	20

The total CO_2 emission from fossil fuel combustion of China is quite big and increases with economic development. It rose from 356 million T-C (ton carbon) in 1980 to 579 million T-C in 1990 at the average annual growth rate 5%. While concerning the per capita CO_2 emission, it was only 0.5 T-C in 1990 in China, which was about half of the world average 1.1 T-C at present time. It is known from Table 5 that coal accounted for 85% of total CO_2 emission in 1990 among all fossil fuels, and the industry (manufacture) was the biggest CO_2 emission contributor among all sectors in 1988, taking the share of 50%. It should be noted that power generation sector ranked the second place with fairly high share of 24% in 1988.

Projected Energy Supply and Use in Year 2000

In this study, two energy demand scenarios of China for the year 2000 are discussed.

In scenario I, assumptions to be concerned with demography, economy and technology are made mainly based on the economy development target which the government has proposed, e.g. the growth rate of GNP would be set as 6% per annum and population growth should be controlled within 16 million each year in the decade of 1990-2000; possible advance of technology; improvement of people's living standard; environmental protection; helpful and useful experiences of foreign countries in industrialization and so on. Thus, this energy demand scenario would be a rational and realistic projection and the major factors affecting energy demand are generated as follows ; average annual growth rate (AAGR) of GNP is 6%; population would reach as high as 1300 million; energy intensity per GNP would decrease at the average annual decline rate (AADR) 1.5% - 2.1% owing to technology upgrading and energy conservation. In China in 1990, GNP was 1740 billion Yuan (Chinese currency), total commercial energy consumption was 686 Mtoe, the exchange rate was 4.77 Yuan to one US$. Based on the major parameters, in 2000 the GNP would reach to 653 billion US$ (at 1990 prices) with per capita GNP of 500 US$ in 2000, and commercial energy demand would increase to 990-1060 Mtoe in 2000 accordingly. However, biomass energy demand would decrease from 210 Mtoe now to 150-160 Mtoe in 2000 according to the plan of reducing biomass energy share in rural areas from 75% to 62% during the period of 1990-2000.

Scenario II is taken as an option in which all assumptions concerning to social, economic development are similar to those in scenario I except energy intensity that is considered to remain the same level in 1990 all time in the future, i.e. AADR keeps zero. As a result, commercial energy demand in 2000 would be 1230 Mtoe, 16-24% higher than that in scenario I.

Major assumptions of energy demand projections and the results of energy demand and CO_2 emission scenarios are listed in Table 6, 7, 8 respectively.

In 1990, China's forest-covering rate was about 13%, i.e. there are 124 million hectares (Mha) of land area covered by forest. Recently, afforestation was 5.3 Mha each year and the accumulative artificial forest has reached to 31 Mha ranking the top place in the world. It is planned that forest-covering rate would rise to 14% in 1995 and 16-17% in 2000, that means net deforestation in coming years would turn to negative, as a result no CO_2 emission from biomass energy should be covered in Table 8.

Table 6 Assumptions of energy demand projections

	Items	Units	1990	2000	
				Scenario I	Scenario II
1.	Population	M	1143	1300	1300
2.	AAGR of Population	%	1.5*	1.3	1.3
3.	Urban popu. share	%	22	27	27
4.	GNP	BUS$	365	635	635
5.	AAGR of GNP	%	9*	6	6
6.	GNP per capita	US$	319	500	500
7.	AADR of energy intensity	%	3.6*	1.5-2.1	0
8.	Energy intensity	Kgoe/US$	1.88	1.52-1.62	1.88

* Figures during the period of 1980-1990

Note : 1. M, B mean million and billion respectively
2. US$ is at 1990 constant prices
3. Exchange rate was 1 US$ = 4.77 Yuan.

Table 7 Energy demand scenarios for the year 2000

		Scenario I		Scenario II	
		demand	Share(%)	demand	Share(%)
1. Fuelwise					
(1) Comm. energy	Mtoe	990-1060	1000 0	1230	100 0
. Coal	MT	1500-1590	75.3-74.7	1960	79.9
. Oil	MT	140-150	14.1-14.1	140	11.4
. N.G.	Bm^3	30-32	2.8-2.8	30	2.3
. Hydropower	Twh	270-310	7.0-7 5	270	5 8
. Nuclear	Twh	30-36	0.8-0 9	30	0.6
(2) Biomass	MT	400-430		400-430	
2. Sectorwise		990-1060	100.0	1230	100
. Agriculture	Mtoe	40-43	4	49	4
. Industry	Mtoe	614-657	62	763	62
. Power	Mtoe	20-21	2	25	2
. Transportation	Mtoe	69-74	7	86	7
. Household	Mtoe	198-212	20	246	20
. Service/commerce	Mtoe	49-53	5	61	5

Note 1. Since it is assumed that all biomass energy would be consumed by household sector, only commercial energy is included while giving sectoral composition of energy consumption

2. Almost 35% of rural households have now used firewood-saving stoves whose efficiency double that of traditional stoves, and biomass energy share would decrease from 75% to 62% in 2000, so that biomass demand could be considered to remain the current level roughly, though the population will increase by the year 2000.

Table 8 CO_2 emission scenarios for the year 2000

		Scenario I	Scenario II
CO_2 emission	(MT)	3080-3270	3900
Carbon content	(MT)	839-891	1063

Note : CO_2 emission only from fossil fuel combustion.

Overview of energy consumption and saving potential by sectors

According to the energy balance table, sectoral composition of final commercial energy consumption in China in 1988 was approximately as follows: agriculture 5.3%, industry 67.8%, transportation 4.8%, service/commerce 4.7%, household 17.4%, among which industry and household were the two biggest energy consumers. However, if primary energy consumption is just compared, the power sector converting primary energy to electricity to be used by other sectors accounted for 21.9%, ranking the second place. Thus, energy conservation in these three sectors are of significance, and brief overviews are mainly given to them below:

Industry sector

Since there are tens of subsectors and thousands of products in industry sector, the energy intensity per value added (EIVA) is generally used as a major indicator to understand the overall energy situation of the sector. Although EIVA of industry declined from 2.0 Kgoe/US$ in 1980 to 1.4 Kgoe/US$ in 1990 (at 1980 prices) with the AADR of 3.6%, there still exists quite big potential for saving energy. If EIVA would drop to 2.1-2.3 Kgoe/US$ in 2000 over 2.7 Kgoe/US$ in 1990 (at 1990 prices) as estimated, and the assumptions of even GNP increase and even EIVA decrease during the period of 1990-2000 are made, cumulative energy conservation of 92-138 Mtoe would be achieved, corresponding to CO_2 reduction of 91-137 Mt (carbon).

In order to realize the target, some major measures could be adopted. Because the EIVA of heavy-industry is about 3-4 times that of light-industry, the heavy and light-industry composition within industry sector have great influence on the energy consumption. At present, the value added share of heavy-industry is 1.4% higher the other, it is estimated that 1% decrease of heavy-industry share would reduce the energy consumption for 5 Mtoe each year and then 50 Mtoe saved in ten years. It seems the composition adjustment is realistic. Moreover, energy consumption of major industrial energy-intensive products such as iron and steel, aluminium, synthetic ammonia, clinker etc. in China are now 10-70% high than that of the advanced level in the world. For example, the comparable energy consumption per ton steel making in China is 700 Kgoe averagely which higher than the typical level in developed nations by 300-400 Kgoe. Steel production in China is now more than 66 Mt a year. By reducing this high energy consumption to 500 kgoe/T, over 13 Mtoe could be saved each year, resulting in total reduction of CO_2 emission by about 130 Mt (carbon) in ten years. Being the big energy consumers in the whole economy, great efforts should be made to reduce the energy consumption in the three sectors of iron and steel, chemical, and building materials.

Power generation sector

The total power generating capacity is now about 130 GW in China, of which hydropower accounts nearly 38 GW. In the fuel composition of thermal power stations (TPS), coal accounts for 87%, oil 12.5%, natural gas 0.5% recently. The total electricity generated in 1990 was 618 Twh in which 126 Twh of hydropower was covered, making up 20% of the total. The average fuel consumption of power generation now is about 280 goe/kwh, that means a 30.7% of generating efficiency. It is possible to decrease this figure by 30 goe in the coming decade by adopting the following measures.

According to electricity development plan up to 2000, the total generating capacity in 2000 would be developed to 240 GW including about 80 GW of hydropower. This implies that there would be about 65-70 GW potential for building new TPS of large-sized generating capacity (e.g. using 300 MW or above generating sets) within ten years from 1991 to 2000. The generating efficiency of large-sized TPS could rise as high as 37% (230 goe/kwh), and these new TPS alone will bring down the average fuel consumption of TPS as a whole by 20 goe/kwh. There would be 18-19 Mtoe saved each year, resulting in reduction of CO_2 emission of 18-19 Mt (carbon) a year.

Great efforts would be made to retrofit the existing generating sets of TPS with a total capacity of about 90 GW, including 100 MW, 125 MW and some 300 MW apart from small-sized generating sets. It is expected that the average fuel consumption could go down from current 280 goe/kwh to 265 goe/kwh by the end of the century in terms of implementing the following major technological measures:

- Replacing existing components with more efficient versions such as of turbine blades, feed pumps, supporting bearings.
- Adding computer aided system for monitoring and controlling.
- Raising the temperature of superheating and reheating steam.

Household sector

The major measure to save energy in residential sector is to improve efficiency of energy use. In urban area, the emphases should be put on popularizing the use o gas for cooking and water heating, and increasing the share of district heating for space heating. The gasification of urban households would increase from 23% in 1990 to 70% in 2000, and efficiency of gas stoves increase from 54% to 57%. Share of district heating for space heating in winter would increase from 7% in 1990 to 12% in 2000, and efficiency increase from 78% to 82%. It is roughly estimated that potential of energy saving in 2000 for gasification and district heating would be 10 Mtoe and 1.4 Mtoe respectively, and corresponding reduction of CO_2 emission would be 10.5 Mt and 1.5 Mt (carbon).

In rural area, great efforts will be given to the widest use of energy-saving stoves, it is intended that share of these stoves would be greatly raised from 35% in 1990 to 90% in 2000. Since the energy efficiency could be improved from 10% of traditional stoves to 20% of energy-saving ones, it is estimated about 65 Mtoe of energy could be saved in the year 2000 and CO_2 emission of 30 Mt of carbon reduced. (only considering coal stove).

In recent years, electricity consumption in household sector accounted for 6% of nation total, and in this sector electricity for lighting is about 70% of the sector total, hence power for household lighting occupies 4% of total power generation. The annual production of electric lamp in China now is around 2 billion, 1.7 billion are incandescents lamp and 0.3 billion are both tube fluorescents and compact fluorescents (trichromatic lamps). The lighting efficiency of fluorescents is averagely 3-5 times that of incandescents. Assuming 1150 Twh of power generation in 2000 and 30% of using fluorescents in 2000 over the 15% in 1990, the potential of electricity saving in household lighting in 2000 would be 6-7 Twh. A rough estimate shows that power needed for lighting nationwide accounts for 8% of total power generation, that means power consumption for lighting in all other sectors except household is approximately equal to that in household alone, if the assumptions are made as the same in household, the total potential of power saving in lighting nationwide would be double to 12-14 Twh in 2000. Thus 3-4 Mtoe could be saved and CO_2 emission of 3-4 Mt of carbon reduced in 2000.

Transportation sector

Although energy consumption of transportation sector only accounts for 5% of total final energy consumption, the gasoline and diesel consumption occupy 44% of total production. In 1990, freight and passenger traffic turnovers were 2630 billion T-km and 560 billion P-km respectively, and railway and road were the two major modes domestically. There still exists great potential for energy saving in the transport sector, if some important issues can be realized.

- Adjustment of the composition of transportation modes. For freight transport, rail share could be reduced slightly in the near future to increase the road share by 3-5%. For passenger transport, rail share could be cut down greatly to keep the balance with passenger transport.
- Use of heavy-duty diesel trucks instead of light-duty trucks in road transport. The diesel trucks share now is about 13%, it could be expected to go up to 22-24% in 2000.
- Replacement of steam locos by diesel and electric ones. Although the heat efficiency of steam locos is only about 9% which is much lower than 25-30% of diesel and electric locos, the steam locos still bear about half of the turnovers of freight and passenger transport, it is planed that steam locos production would be stopped by 1995 and the traffic turnover of freight and passenger by steam locos would be limited within 10-15% by 2000. In turn, electric locos would take 50-55% of total traffic turnovers.
- Improvement of energy efficiency of transport vehicles. It is hoped that the fuel consumption intensity in rail and road transport could decline by 30-35% in the year 2000 through the ways mentioned above and improvement of management.

With the social and economic development, traffic turnovers will also increase. If the assumptions are made as that both freight and passenger traffic turnovers would double, and the consumption intensity would all drop by 40% by the year 2000 over 1990, it would give the energy conservation potential of about 40 Mtoe in 2000 and CO_2 reduction of 36 Mt of carbon.

Strategies of abating CO_2 emission

The ways of mitigating CO_2 concentration in the atmosphere might include great efforts made in two aspects : (1) to limit sources releasing CO_2 and (2) to develop sources assimilating CO_2. Now, fossil fuels combustion are thought as the major source to generate large amount of CO_2. With the social and economic development, energy demand will result in CO_2 emission rise. Hence, realization of CO_2 reduction will need to cut down energy consumption and then hurt economic development. This contradiction could be alleviated through the possible ways such as improvement of energy utilization efficiency, replacement of carbon fuels by non-carbon fuels (hydropower, nuclear, solar, wind, geothermal etc.). CO_2 assimilation can be realized by afforestation and other scientific technologies, the former is commonly considered as the most realistic measure at present time.

Improvement of energy utilization efficiency

Power generation, industrial boilers and kilns, urban and rural households are now the big energy consumers in China, and at the same time there exist fairly large potential of energy conservation, about which some discussions are made here.

(1) Power generation

There are totally 90 GW of TPS in China now, 87% of which are coal-burnt power plant burning 280-300 Mt of coal each year, traditional generating technology is still widely used, advanced technologies such as pressured fluidized bed combustion (PFB) and combining cycle (CC) only occupy a very very small share. It is estimated the existing capacity of PFB and CC (oil-burnt) are about 500 MW respectively and the efficiency are nearly 38% for PFB and 37% for CC which are much higher than 30.7% of average efficiency in power sector. If the capacity of PFB would be expanded to 2 GW in 2000 and CC to 1.5 GW, 0.7 Mtoe could be saved each year by using advanced technologies. Since PFB and CC are considered to be the same as traditional technology to use coal as fuel, it is assumed that the costs of operation & maintenance are the same, therefore only the difference of investments and fuel cost saving should be treated in assessing the cost of reducing CO_2 emission. Assuming the investment cost of traditional TPS, PFB and CC are 2100, 2900, 3500 Yuan/kw (1990 prices), i.e. 440, 610, 730 US$/kw at the exchange rate 4.77 Yuan/US $ (same in the analysis hereinafter), and life time 30 year for all of them, it is resulted that the total potential for CO_2 reduction over the life time are 9.5 Mt of carbon and 5.2 Mt of carbon for newly installed PFB and CC technologies respectively, and the specific costs would be 12 US$/T-C for PFB and 30 US$/T-C for CC.

(2) Industrial boilers and kilns

Industrial boilers now are the most popularized energy end-use devices in industry, service/commerce, and household sectors in China, with the number of 0.4 million (excluding those in power station and steam locos) and total capacity of 0.8 million steam-ton. These large number of boilers consume about one thirds of total coal production, i.e. 300-350 Mt of coal, at the comparatively lower heat efficiency -- 55-60% averagely, owing to small average capacity (around 2 steam-ton/boiler), low level of automatic control, bad adaptability to different kinds of fuels, poor operating skill and management etc. However, it is planed that to improve the average efficiency of boilers from 55-60% to 65-70% in 2000 by technological renovation and other measures. If half of the existing boilers would be retrofitted by 2000 resulting in the efficiency improvement from 55% to 65%, energy conservation would be 13-18 Mtoe in 2000, that means CO_2 reduction of 13-19 Mt of carbon a year would be achieved. Furthermore, assuming a new boiler costs 17 thousand US$ averagely, retrofitting investment is about one thirds of boiler cost, and life time is 10 years after retrofitting, the specific cost for reducing CO_2 emission would be given to be 5 US$/T-C under the condition of same operation & maintenance and fuel cost.

Industrial kilns used in the production of iron and steel, building materials, chemical products etc., now account 140 thousand consuming about 140 Mtoe of energy annually. The energy efficiency of kilns is much lower than the advanced level in the world, averaging 20-25% because of backward technologies in design and manufacture, small average capacity, poor management and operation, low energy price and so on. So that there exists also a significant potential of energy conservation to improve the utilization of kilns. If the efficiency of one thirds of existing kilns could be raised from 23% to 30% averagely by the year 2000 by retrofit and other measures, energy conservation would reach 11 Mtoe in 2000, resulting in CO_2 reduction of 11 Mt of carbon a year. Moreover, if some further assumptions are made that the average cost of industrial kilns is 130 thousand US$/kiln, retrofitting investment is about half of the kiln cost, and life time lasts 8 years after upgrading, as a result the specific cost of CO_2 reduction would be 19 US$/T-C in the condition of same operation & maintenance and fuel cost.

(3) Gasification for urban households

At present, about 18% of total commercial energy consumption is distributed to household sector, of which 55% for urban households. Cooking, space heating and electricity are the three major end-use, rough estimate shows that cooking and water heating share about 40% of energy consumption in urban households, i.e. 27 Mtoe fuels were consumed in 1990. Briquettes, raw coal and gas (including LPG, coal gas, N.G.) are the main fuels for cooking in urban area. Among the gas supply composition, LPG accounts 38%, N.G. 42%, coal gas 20% recently, and the weighted conversion efficiency from primary to secondary energy is taken as 92%. Assuming the efficiency of gas stoves to be 55%, the energy utilization efficiency is about 50% which is much higher than 22% of coal stoves. There was about 23% of urban households provided with gas supply in 1990, if the target of 70% gasification rate could be fulfilled by 2000, it would obtain 12 Mtoe of energy conservation and CO_2 reduction of 13 Mt of carbon in 2000. Although fuel cost of gasification will go up by increasing LPG or N.G. supply whose prices are 5-10 times that of coal, the money saving from great amount of coal reduction will balance or surpass the increase, the fuel cost will be neglected for simplicity. If capital investment of gas supply facilities is assumed to be 400 US$ per household, operation & maintenance cost to be 2% of capital cost, the life time to be 30 years, and the social discount rate to be 10% (same below), the specific cost of gasification would be 50 US$/T-C.

(4) Energy-saving stoves for rural households

Energy-saving stoves include two types: coal-saving and firewood-saving ones. Since the net deforestation will become negative, CO_2 emission from biomass energy combustion can be treated to keep balance, and only CO_2 reduction technology of coal-saving stove is discussed here. The popularization rate of coal-saving stove would greatly increase from 35% in 1990 to 90% in 2000, and efficiency from 10% to 20%, hence the cumulative energy saving would be 290 Mtoe and 305 Mt-C of CO_2 reduction accordingly within 10 years of life time. While compared to traditional coal stoves, the new type of stoves can save half amount of coal, so the fuel cost per year would be 10.8 US$/household under the condition for coal price 12 US$/T. At present, the coal-saving stove costs about 42 US$/household, if the maintenance cost is assumed to be 10% of the stove cost, the specific cost of reducing CO_2 emission would be 0.3 US$/T-C.

Replacement of carbon fuels by non-carbon fuels

(1) Hydropower

Hydropower is one of the most clean energy and its investment cost is much lower than that of solar energy, so that hydropower now is the best alternative non-carbon energy for fossil fuels. In China, there are abundant hydro resources, it is estimated that the exploitable hydropower reaches as much as 380 GW which ranking the top place in the world. but only about 10% of available hydropower is utilized so far, i.e. it only accounts for 1/5 of total power generation, thus there exists much bigger potential in building hydropower stations in the coming decades. At present, a lot of hydropower plants with total capacity of some 20 GW is under construction. Besides, some pumped storage hydropower stations will also be constructed in order to ease the peak demand from power networks by operating in parallel with big thermal and nuclear power plant. The existing hydropower capacity is around 40 GW, it is planned that the capacity would double to 80 GW in 2000, thus the 40

GW of newly built hydropower plant would replace about 76 Mt of coal and reduce CO_2 emission of 40 Mt of carbon a year.

If the investment cost of hydropower station is 920 US$/KW, the life time is 50 years, and operation & maintenance cost is assumed to be 1% of the investment cost, it would give the specific cost of reducing CO_2 emission 20 US$/T-C.

(2) Nuclear power plant

Nuclear power is another major non-carbon energy widely used in the world, but there is no nuclear electricity to be used in China so far. It should be pointed out that China possesses both nuclear energy resources and nuclear technologies required. Now, two nuclear power stations are being constructed, they are located in east and south China where economy has well been developed but still suffered by serious power supply shortage. One station built by China itself in east China with the capacity of 300 MW will be put into operation in 1992, the other with the capacity of 2 x 900 MW in south China is a joint venture project of China, Britain and France and will be completed in 1992/1993. The rapid development of nuclear power would emerge in the first half of next century, so that only some 6 GW of nuclear power capacity by the year 2000 are taken as the target of short-term nuclear power development. If the plan could be fulfilled then, about 9.5 Mt of coal would be replaced by the new added nuclear plant, and CO_2 emission of 10 Mt of carbon be reduced in 2000.

According to roughly estimation, the investment cost of nuclear power station is 750 US$/KW, and the operation & maintenance and fuel cost are 14 US$/KW and 32 US$/KW per year respectively. If the life time of nuclear plant is assumed the same as TPS, being 30 years, the specific cost for reducing CO_2 emission by this technology would be 24 US$/T-C.

(3) Other renewable energy

Solar, wind and geothermal are the major types of renewable energy which could be developed and used realistically in China in the near future. Although the total renewable energy supply of these three types amounted to 0.3 Mtoe a year in past few years, which occupied a very very small proportion (0.04%) of total commercial energy supply, as an alternative option of clean energy in long-term energy strategy plan, attentions should be paid to the development of renewable energy. Based on overviews of current situation, some simple scenarios are generated for comparison with other technologies.

China is rich in solar energy resources, it is estimated that the total annual amount of radiation ranges 3,345-160,000 MJ/m^2, but the utilization of solar energy is only in the stage of research and application at small scale. Solar water heaters, solar drying, solar house and solar photovoltaics (p.v.) are the major devices using solar energy. The total amount of installed solar water heaters now reaches 1.5 million m^2, mainly for domestic hot water supply while a few for public bath rooms and other commercial uses in urban and rural areas. For solar dryer, about 110 sets in different types have been set up with a total aperture area of 11 thousand m^2. According to the statistics made in recent years, there are some 800 sets of passive solar house with a total floor space of 0.3 million m^2 built nationwide covering the varieties of rural residential house, urban apartments, school, hospital and so on. And, about 0.12 million sets of solar cookers have been produced and used in rural households totaling 0.2 million m^2 of aperture areas and saving some 50 thousand tons of straws and stalks every year. Finally, the cumulative installed solar PV power now is about 1.3 MW which mainly used for transportation, telecommunication, meteorological and earthquake station, medical, and military.

There are rich potential in wind energy along the coast area and nearby isles in south-eastern China, the annual average wind speed ranges 6-9 m/sec, and the wind speed between 3-20 m/sec happens more than 6000 hours annually suitable for develop in medium- and large-scale wind power generators and then connecting to power grid. On mainland the regions with high wind potential are located in the north of Inner Mongolia where the annual average wind speed reaches 4-6 m/sec, and the wind speed ranging 3-20 m/sec occur 5000-6000 hours a year. The development of mini wind turbine generators for individual application is of bright perspective to solve the problem of power shortage in herdsmen households. The small-scale wind power sets now numbers about 0.11 million, and the total installed capacity which including that of medium-scale sets amounts to 15 MW. Additionally, wind pump is also developed in places where exists abundant resources of both wind energy and water. At present, wind pump comes up to the number of 1600 with a total capacity of 2 MW for easing energy supply shortage in rural areas.

According to the preliminary statistics, China possesses rich geothermal energy resources, the natural heat discharge of hot springs is some 110 PJ, and the total geothermal energy resources reaches to 3200 GW in which the potential for power generation over 1 GW. The high-temperature geothermal resources are mainly centered in southern Tibet, Western Yunnan and eastern Taiwan. Among the total number 5000 of identified geothermal outcrops, including 3000 hot springs and 2500 wells, about 1000 locations have been exploited for various kinds of use. Now, the total capacity of geothermal power generation has developed to 21 MW, the total floor space of greenhouse using geothermal water amounts 1.2 million m^2, and 19 application projects for space heating in winter by geothermal consume 1.2 PJ of energy annually.

The scenarios of potential of major renewable energy development up to the year 2000, costs of various technologies, life time, overall CO_2 reduction during life time, specific cost for reducing CO_2 are summarized in Table 9.

Afforestation

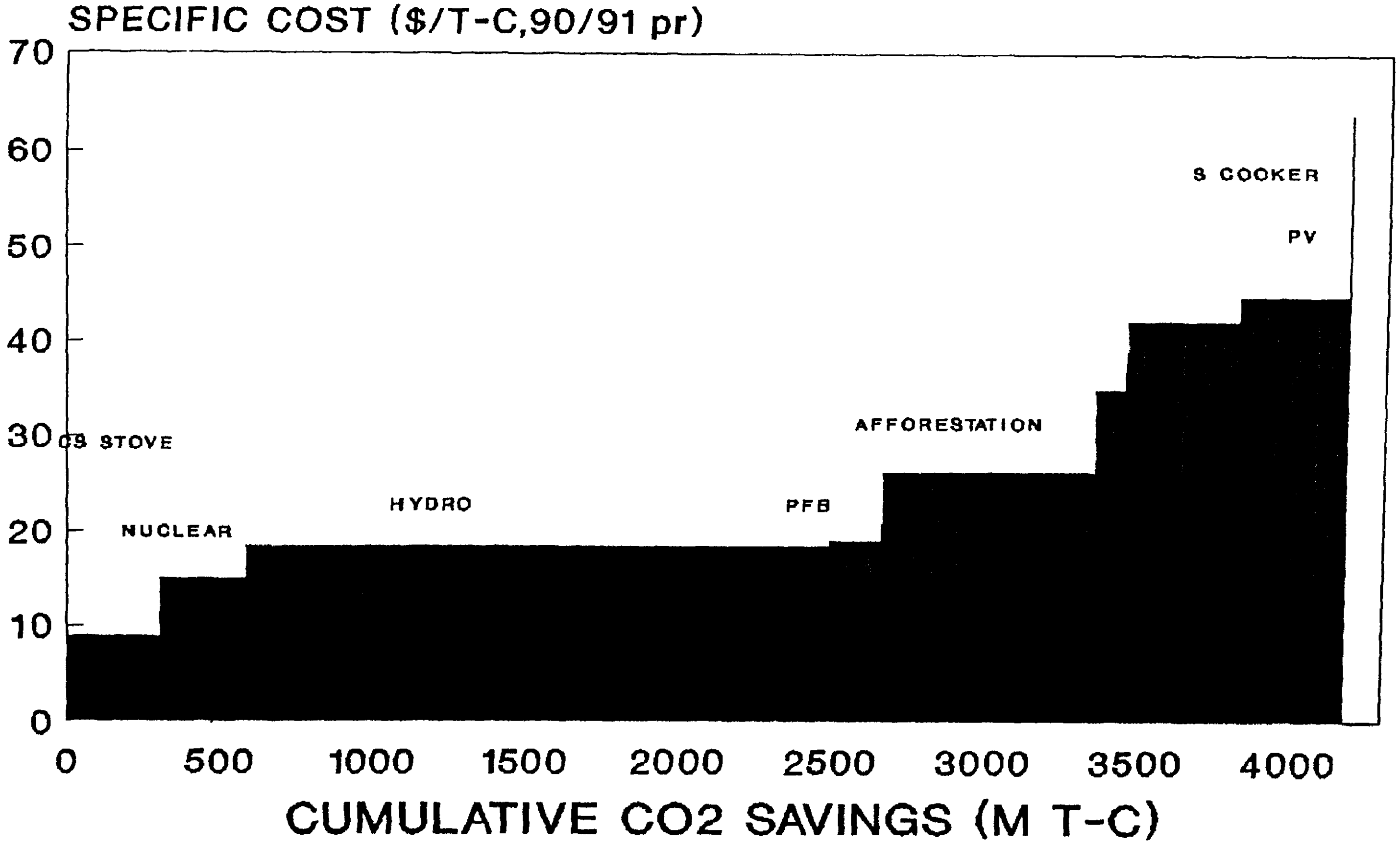
As mentioned previously, an afforestation plan in China has been proposed, that is to afforest 16-17% of China's land area by the end of this century over the share 13% in 1990. Based on the target, 29-38 million hectares of land would be planted in the decade of 1990-2000. Under the assumptions of a growing wood stock of 60 m^3 per hectare, a wood density of 0.75 ton/m^3, and a carbon content of 45% of the weight, the total carbon fixed in the wood from the increase of plantation would be 590-770 million T-C. The average cot of afforestation now is estimated to be 320 US$/ha., the cost of labour force and maintenance to be 3% of the investment cost and to be needed for 8 years. While calculating the total investment, a very important factor should be taken into consideration, i.e. the survival rate of plantation. If it is assumed to be 60% in China, that means 48-63 million hectares of land should be planted in order to realize the same target. Finally, the specific cost of assimilating carbon by afforestation would thus be 30 US$/T-C.

Table 9 Strategies for abating CO_2 emission (upto the year 2000)

	Potential (new added)	Total cost (in US$)	Life time (years)	Cumulative CO_2 reduction during life time (million T-C)	Specific cost of CO_2 reduction (US$/T-C)	Specific cost of CO_2 reduction (US$/T-C)
1. Coal-saving stove	64 MH	1.5/H	10	305	0.3	9
2. Retrofit of existing boilers	0.2 million	5700	10	160	5	19
3. Pressured Fluidized Bed	1.5 GW	150/KW	30	9.5	12	19
4. Retrofit of existing kilns	46 thousand	65000	8	92 5	19	35
5. Hydropower	40 GW	1010/KW	50	1900	20	18.4
6. Nuclear power	6 GW	1185/Kw	30	284	24	15
7. Solar heaters	1.9 M m^2	115/m^2	15	8	25	21
8. Afforestation	34 Mha.	370/ha.		690	30	26.3
9. Combining cycle	1.0 GW	290/KW	30	5 2	30	37
10. Wind generation	48 MW	1270/KW	20	1.5	42	39
11. Solar P.V.	9.3 MW	815/KW	20	1.5	49	45
12. Urban gasification	49 MH	475/H	30	360	50	42.3
13. Solar cooker	60 thousand	50	10	0 05	68	64

Note : 1. US$ is at 1990 price.
2. MH means million households.
3. Total cost includes investment cost, and operation & maintenance and fuel cost which have been discounted to the start year at the 10% of social discount rate
4. Specific cost of CO_2 reduction in 5th column covers the costs of capital investment, operation & maintenance, and fuels, but that in 6th column only involves capital investment cost.

COST OF CO2 ABATEMENT WITH SELECTED TECHNOLOGIES IN CHINA



CHAPTER 5 : INDIA COUNTRY PAPER

Sujata Gupta
Neha Khanna

Tata Energy Research Institute
9 Jor Bagh, New Delhi 110 003
India

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Executive Summary

Total energy consumption in India was of the order of 300 million tonnes oil-equivalent (MToe) in 1989-90, of which about 120 MToe (40%) was biomass-based fuels. The total carbon dioxide emissions from fossil fuels were about 159 million tonnes of carbon (MTC).

The potential for reducing primary energy consumption, principally of CO_2-producing fuels, without reducing end-use services is examined in this paper. Three strategies have been investigated: increase in energy utilization efficiency in the electricity, industrial, transport, agricultural and domestic sectors; larger deployment of renewable energy technologies; and afforestation. Table S-1 lists the potential (over the lifetime of each option), the investment cost, and the specific CO_2 removal cost for each option.

The largest potential for reducing CO_2 emissions is through afforestation (i.e. a total of 1540 million tonnes of carbon over 35 years). The energy-related options have specific reduction costs ranging from approximately US $ 3/T carbon to US $ 628/T carbon.

able S-1: Potential and cost of various CO_2 emission reduction options

	Potential for Reduction in CO_2 Emissions-over life (MT of Carbon)	Investment Cost (Bill-ion, US $)	Specific Cost of CO_2 Redu (US $/T
. Increase in Energy Utilization Efficiency			
1.1 Electricity Sector			
* Electricity Generation			
- Coal Washing	192 25	0.58	
- Replacement of Coal TPS by Gas Combined Cycle TPS	82.5	1 68	
* Transmission & Distribution			
- Reduction in T&D Losses	210	7.21	
1.2 Industrial Sector			
* Improved Housekeeping	28	0.38	
* Installation of Energy-Efficient Equipment, and Better Instrumentation & Control	35	1.15	
* Upgradation of Technology	25	1.92	
1.3 Transport Sector			
* Enhanced Urban Public Transport			
- Increasing Bus Fleet	9 35	0.83	
- Metro Rail Systems	122 4	14.86	
* Enhanced Rail Freight Movement	147	32 43	
1.4 Agricultural Sector			
* Pumpset Rectification	50.6	5 1	
1 5 Domestic Sector			
* Improved Firewood Chulha	6	0 08	
* Improved Lighting			
- Replacement by Tube Fluorescent	37.2	0 44	
- Replacement by Compact Fluorescent	35 7	3.06	

le 5-1 Contd..

eployment of Renewable Energy Technologies			
2 1 * Biogas plants	18.40	6.41	348
* Solar thermal systems	96	1.83	19
2.2 Electricity from Other Renewables			
* Biomass	128.9	4.8	37
* Wind	43.0	4.5	105
* Small Hydro	51.6	2.4	47
* Sewage Sludge	1.4	0.075	54
* Distillery Effluent	4.0	0.03	7
* Municipal Solid Waste	4.6	0.32	70
* PV Pumps	1.1	0.09	82
* Windpumps	0.3	0.055	182
* Solar Energy	5.73	3.60	628
Afforestation	1540	42.04	27

Methodology

In this study, we have considered only those options which can be implemented by the turn of the century. For each strategy, the investment required (in 1990 prices), the realistic potential, and the CO_2 emissions saved/fixed (measured in tonnes of carbon) over the life time of the option are estimated (as compared to the "do-nothing" scenario). The various CO_2 abatement options are ranked in ascending order of specific investment costs of CO_2 reduction. The cost curve is generated by plotting the cumulative potential for reduction in CO_2 emissions on the horizontal axis and the corresponding specific costs (in ascending order) on the vertical axis. The area under the curve gives the total quantum of investments required to implement these strategies. (Figure 1). The 1990 exchange rate of Rs 16.65 to a US $ is used.

As brief analysis of the constraints to the implementation of the identified strategies and the institutional mechanisms that would be suitable for channeling the incremental inputs is also undertaken.

It should be noted that this paper is an analysis of strategies: both energy savings and consequent reduction in CO_2 emissions, and the investments required, which are quantified only to a first approximation. A detailed study of each strategy would be required to obtain more precise numbers.

Increase in Energy Utilization Efficiency

The total "useful" energy consumption in India today, i.e., the amount of energy which is ultimately available for the desired level of energy services, is about 70 million tonnes coal-equivalent (MTCE), whereas the gross energy supply is in excess of 400 MTce[1]. The overall thermal energy efficiency of the economy is, therefore, only 17.5%. In part, this low efficiency is because of the large amount of biomass supply which is utilized at an efficiency of about 8%[2]. However, biomass fuels apart, even commercial energy utilization efficiency is less than 25%. There is scope, therefore, for increases in energy efficiency.

The Inter-Ministerial Working Group on Energy Conservation set up in 1981 estimated that an economy-wide saving of 25% in commercial energy consumption seemed possible[3]. Appendix I lists a summary of the measures suggested by them, the savings expected, and the investments required. The projected savings were : 25% in the industrial sector, 20% in the transport sector, and 30% in the agricultural sector with a total investment of Rs 82.04 billion (US $ 4.9 billion)

This section examines the potential for energy conservation in the Indian economy, and evaluates the resource requirements to implement these conservation measures.

Electricity Sector

Electricity Generation : The installed electricity generation capacity at the end of 1989-90 was 62,534 MW and the total generation during the year was about 233 TWh. Approximately 67% of the installed capacity is in thermal plants which contributes over 70% of the total electricity generated[4]. The efficiency of coal conversion in Indian thermal power stations (TPS) is low: the average gross conversion efficiency is 28%, and the average net efficiency is about 25%[5]. More than 70% of the TPS installed capacity operates at efficiencies below 30%, and 25% of capacity operates at efficiencies below 25%. The present design gross efficiency is about 32%, and the system-wide design average would probably be about 31%. Currently, worldwide, design efficiencies are similar (about 35%), but elsewhere, in general, operating efficiencies are close to the design values. Enhancing TPS performance so that the operating efficiency approaches the design efficiency would increase their aggregate power output (at the same coal input rate) by nearly 15%: implying that CO_2 emissions per kWh delivered would decrease by nearly 12%.

Some of the power generated in a TPS is utilized to run plant auxiliaries, such as coal grinding mills, air blowers, ESP, etc., and some power is lost in transformation (to transmission voltage), switching, etc. Presently, at the national average, about 10% of the power generated in a TPS is used internally[5]. Consequently, the net conversion efficiency is 90% of the gross conversion efficiency. Decrease in in-plant consumption would, therefore, also result in a reduction in specific CO_2 emission (kg carbon emitted per kWh delivered at TPS busbar).

Coal Washing

The principal cause for low TPS efficiency is poor and varying quality of coal as well as poor maintenance and upkeep. High-ash coal, by itself, does not lower efficiency (in fact, boilers burning high-ash coals have the same design efficiency as those burning low-ash coals). However, coal supplied to TPS is largely from open-cast mines and has a lot of non-coal material (principally shale and rock) mixed with it. This results in poor combustion, as well as in high power requirement for grinding. Washing coal before it is supplied to TPS would greatly reduce the non-coal matter that travels with it. Boiler efficiency with washed coal rises to about 89.5%[6], (from 77% with unwashed coal, on the average) and in-house electricity consumption reduces from 10% to 8% of gross generation[7].

Thus, the strategy of washing coal alone would increase net efficiency by 18.8%, i.e., net efficiency would increase from the current 25% to 29.5%. The specific CO_2 emission would fall from 0.327 kgC/kWh to 0.266 kgC/kWh.

There are no washeries for non-coking (power grade) coal in India. The principal reason for their absence is the lack of an integrated policy as well as the lack of capital to set them up. A washery for a 1040 MW TPS costs Rs 320 million at 1990 prices[7] (US $ 19.21 million). The total potential for efficiency upgradation (by 18.8%) is estimated to be 45% of the total TPS installed capacity. This works out to a total capacity of 18,850 MW. In addition, washeries for future TPS coal supplies would also be required. Official demand projections for future capacity requirements are high, but in this study we assume that total coal-based electricity generation capacity would be about 70,000 MW in the year 2000. This implies capacity addition of about 28,000 MW between 1990 and 2000. Further, we assume that the washed coal would continue to be 45% of total coal supplies to TPS; consequently washeries for supplying coal to 31,500 MW of TPS would be required. This implies a capital requirement of Rs 9,700 million (US $ 585.58 million). The annual CO_2 emissions due to coal combustion in TPS would decrease from 91.56 million tonnes carbon to 83.87 million tonnes carbon. Assuming the life of a coal washery to be 25 years, this would save 192.25 million tonnes of carbon over its lifetime.

Substitution of Coal by Natural Gas

Substitution of coal by gas to the extent possible would also reduce CO_2 emissions. Current plans for gas-based TPS call for an addition of 6203 MW during 1990-95. Additions during 1995-2000 are estimated to be 4618 MW. Apart from these plans, all the gas presently flared off the West coast could be utilized for power generation in West India which would release an equivalent amount of coal.

Currently, over 2.5 billion cu.m of natural gas are flared in the Bombay High basin annually[4]. This gas could generate about 12 TWh of electricity which implies an installed capacity of about 2200 MW of gas-based combined cycle TPS, or an equivalent 2,500 MW coal-based TPS using 6.83 MT of coal per year. The installation of 2,200 MW of gas-based combined-cycle capacity would cost Rs 28,000 million, (US $ 1682.68 million) and would result in CO_2 emissions reduction of 3.3 million tonnes of carbon annually. Assuming a life of 25 years for the gas capacity installed, the specific cost is Rs 339 (US $ 20.36) per tonne of carbon.

Transmission and Distribution

Transmission and distribution (T&D) losses in the Indian power system are estimated at 22%[4]. However, owing to the practice followed by some State Electricity Boards (SEBs), of diverting a certain portion of non-technical/commercial losses towards unmetered power supply to agricultural consumers, the actual T&D losses may be somewhat higher. The Committee on Power[9] recommended a realistic target of reducing T&D losses to a level of about 15% by the year 2000. However, little has been done in this direction so far. In fact, percent T&D losses increased until the mid-1980s and have remained fairly stable since then (see Table 1).

Table 1 : T&D losses(%)

1970-71	17.5
1976-77	19.8
1982-83	21.1
1985-86	21.7
1987-88	21.5

Source: (i) CEA, Public Electricity Supply, All India Statistics (General Review), Various Issues.
(ii) CMIE, Current Energy Scene in India, July 1989.

In order to identify suitable strategies to reduce T&D losses, it would be necessary to know the level of T&D losses taking place at various voltage levels in the T&D system. On the basis of available information, these losses have been estimated and are presented in Table 2 below.

Table 2 : Percentage Losses at Various Line Voltages

	% Losses		
	Line	Transformation	Total
EHT (66 kV and higher)	4.0	0.5	4.5
33 kV	3.0	1.0	4.0
11 kV	6.0	1.0	7.0
415 volts	5.5	2.0	7.5
Total	18.5	4.5	23.0

Source : 26

It is apparent from Table 2 that a major portion of the losses take place at 11 kV and lower voltage levels. These also include non-technical losses, arising from under-recording in meters (most mechanical meters tend to slow down with age), meter tampering, defective meters, and pilferage etc. Losses arising from the latter three factors may be reduced with more care in testing and replacement of meters in time, and strict enforcement of laws to ensure that meters do not get tampered and that electricity theft does not take place. Also, a coordinated programme of periodic meter-testing and recalibration needs to be introduced.

It is estimated that out of 23% T&D losses, technical losses amount to 15% and non-technical losses including pilferage etc. 8%. In order to arrive at "order-of-magnitude" estimates of additional T&D investment requirements to reduce losses to 19% by the end of the 8th FYP period (i.e., 1995-96), it is assumed that (i) non-technical losses are reduced from the present level of 8% to about 6%; and (ii) technical losses are reduced from the present level of 15% to about 13%.

Total investment in T&D systems in India until end of 7th FYP period = Rs 35,000 crores (1990 prices)

Tentative investment level for T&D in 8th FYP period = Rs 20,000 crores (1990 prices)

Total investment for T&D until end of 8th FYP period = Rs 55,000 crores (1990 prices)

This level of investment gives technical losses of 15%, which we aim to reduce to about 13% by end of the 8th FYP period. Considering an empirical relationship between T&D losses and T&D investment, the additional investment required in T&D systems by end of 8th FYP period is approximately Rs 40800 million (US $ 2450.45 million)

Based on past trends an estimated expenditure of Rs 335,000 million (US $ 20120.12 million) would be necessary over the period 1995-2000 to maintain the technical losses at 13%. An additional expenditure of Rs 80,650 million (US $ 4843.84 million) would be required to reduce technical losses from 13% to 11% over 1995-2000 (see appendix II for details).

The non-technical losses in the year 2000 are assumed to be 5% - the total T&D loss will then be 16%.

It may be mentioned that this is only the lower bound of investment requirement for reduction in technical losses as some losses also occur due to improper electrical connections, improper conductor sizing etc., which are not estimable by the empirical formula used.

Incremental expenditure of nearly Rs 120 billion (i.e., US $ 7.21 billion) would be required to decrease T&D losses from 23% to 16% between 1990 and 2000. Assuming a capacity of 100,000 MW in the year this would result in annual reduction in CO_2 emissions of 10.5 million tonnes carbon if the entire reduction in generation possible due to increased T&D efficiency is assigned to coal-based generation. Assuming a lifetime of 20 years for a T&D system, this implies a saving of 210 million tonnes of carbon and a specific cost of Rs 571 (US $ 34.29) per tonne of carbon.

Industrial Sector

The industrial sector (manufacturing industry) in India has traditionally been the largest user of commercial energy in the Indian economy. In 1988-89, about 34% of the total commercial energy available was consumed by this sector. The contribution of non-commercial energy sources, such as bagasse, rice husk and solar energy, to this sector is negligible overall, though significant in some industries (for example, sugar mills). The energy use by the industrial sector as a whole is detailed below in Table 3.

Table 3: Energy Consumption Pattern in the Industrial Sector

(Mtoe)

Years	Coal	Oil	Natural Gas	Electricity	Total
1981-82	28 958	8 864	1 003	4.479	43 304
1982-83	32.434	9 292	1 51	4 471	47.707
1983-84	34.017	9 47	1 772	4 819	50 078
1984-85	33.175	10 31	2.142	5.319	50 946
1985-86	36 109	10 413	1 083	5 654	53.259
1986-87	38 49	10 521	3 165	6 035	58.211
1987-88	35 478	11.0	3 859	6 501	56 838
1988-89	39.703	10 876	4 681	7.118	62 378

Source . 4

Energy Conservation

It has been estimated that the energy conservation potential that could be realized in the 8th Plan is 15% and 10% in the 9th plan. The Inter-Ministerial Working Group[3] calculated that with only the installation of new equipment the savings from coal-based, oil-based and electric machines would be about of 20%, 20% and 15% respectively. In the short-term, implementation of improved housekeeping measures, training of personnel, and energy audits could save about 7.1 MTce, or 2.8 MT carbon emissions on an investment of Rs 6384.3 million (US $ 383.44 million). The expected savings in monetary terms is Rs 6,160 million (US $ 370 million) annually. The medium term measures include the installation of waste heat recovery systems, replacement of inefficient boilers, introduction of instrumentation and control systems and adoption of better technology at a cost of Rs 19153 million (US $ 1150.33 million). The savings forecast were 8.9 MTCE or Rs 7,720 (US$ 463.66) per annum. This implies annual CO_2 emissions reduction of 3.5 MT carbon. In the long-term introduction of new systems e.g., cogeneration systems, adoption of new energy-efficient technologies and computerization of process control operations are expected to yield a savings of Rs 5,370 million (US $ 322.52 million) annually i.e., 6.2 MTce. Carbon emissions would reduce by 2.5 MT carbon per year. The investment required for this was estimated at Rs 31921 million (US $ 1917.18 million) The adoption of these measures in the short, medium- and long-term are expected to realize the estimated savings potential for the 8th and 9th plans.

While there are many reasons for the low level of energy efficiency in the Indian industry even 17 years after the oil shock in 1973, the major ones are : lack of awareness and training, shortage of capital, inappropriate incentives, high interest rates, and large customs duty on imported equipment. Energy conservation policies need to focus on these issues.

In addition to reducing the fossil fuel consumption in industry significantly through energy conservation measures, there is a need to bring in solar thermal energy low-grade heat applications on a large scale. A target of (an incremental) 5 per cent of total energy use from renewable energy sources (solar, wind and biomass) in each of the next two five-year plans, (i.e., till the year 2000) seems plausilble.

Transport Sector

In the years since the Inter Ministerial Working Group report was submitted, the level of transport services in the country has increased by over 40%[10]. The energy demand of the transport sector over the same period has, however, increased by nearly 70%. The disproportionately higher rate of growth of energy consumption is primarily because of two structural shifts that have occurred in the transport sector. The first is the decreasing share of railways in both freight and passenger movement, and the second is the increased share of personalized modes of transport in passenger traffic. Thus, the share of mechanized road transport in passenger traffic increased from 67% in 1970-71 to 78% in 1987-88 [TEDDY 1989]. Again, in freight traffic, the share of road transport increased from 34% to 51% over the same period [TEDDY 1989]. It is essential to reverse these trends if the rate of energy consumption is to be no more than the rate of growth of transport services.

Increased rail track length, higher efficiency and faster movement in the railways and enhanced public transport systems are necessary for reversing the high rate of energy consumption growth in the transport sector.

Enhanced Public Transport System

A reliable forecast for total urban transport demand is estimated by the "Study Group on Alternative Systems of Urban Transport"[11]. According to this study, under the business-as-usual scenario, the total travel demand for 83 cities of different sizes with population above 0.25 million is estimated for the year 2001, and given in Table 4.

Table 4 : Projections of Urban Travel Demand for 2001

Population Range (Million)	Median Population	No. of Cities	Population (Million)	Travel Demand BPKM* per year
8+	13	4	52	314.5
3 - 8	6	3	18	59.8
2 - 4	3	4	12	25.9
1 - 2	1.5	15	22.5	25.6
0.5 - 1	0.75	36	27	15.6
0.25 - 0.5	0.375	21	7.9	1.4
Total		83	124.4	442.8

[* BPKM = Billion Passenger Kilometers]

Of this total projected traffic demand of 443 BPKM in the year 2001, it is estimated that nearly 20% of the travel demand will be met by sub-urban and urban rail traffic systems while the remaining 80% (i.e. 358 BPKM) passenger travel demand will be met by road transport.

Road Transport

There has been an exponential growth in motorized vehicles, with an average growth rate of nearly 13% per annum in the last decade. The growth rate of two-wheelers has been very high (16.6%). The number of cars has also been growing at a higher rate (6.9%) than buses (5.7%), clearly indicating a shift from public transport to personalized transport [Centre for Monitoring the Indian Economy, Basic Statistics, Vol.1, various issues]. Accordingly, if the present trend of vehicular growth continues, it will result in increased energy demand by this sector as well as increased congestion and pollution. In this study we consider two scenarios : (1) Business-as-usual (BAU) or as per present trends, and (2) A scenario with increased share of public transportation. We have made the following assumptions :

- Total travel demand by road for the 83 cities is as in Table 4.
- In the BAU scenario, modal split for public transport will be 57% and that of cars 9%[12].
- In the alternative scenario, public transport shares will be 80% and that of cars 4%.
- The balance trips to meet total travel demand is split in the ratio 2:1 between two-wheelers and three-wheelers in both the scenarios.

Overall, the aim is to reduce work trips by personalized modes of transport (which presently constitute about two-thirds of the total trips by cars and two-wheelers), by two-thirds. This traffic would be diverted to buses. Further, bus capacity is also provided to cater to 50% of the three-wheeler traffic.

The results are summarized in Table 5.

Table 5 : Implications of Alternative Scenario

	As per present trends					As per alternative scenario				
	Bus	Car	2W	3W	Total	Bus	Car	2W	3W	Total
Annual Passenger Kms (10^9)	205	33	80	40	358	288	14	36	20	358
Modal Split (%)	57	9	22	12	100	80	4	10	6	100
No. of vehicles (10^3)	62	1173	7809	532	9576	87	488	3542	260	4377
Passenger car units (10^3)	186	1173	3904	532	5795	261	488	1771	260	2780
Fuel (10^3 TOE)	1270	1012	1277	733	4292	1786	421	579	359	3145
Annual CO_2 Emissions (10^3 tonnes C)	1076.5	860.2	1085 5	623	3648.2	1518 1	357.9	492 2	305.2	2671.6
Cost (Rs.million)	33790	52540	41020	22370	149720	47540	21860	18610	10960	98970

Source : 11

Thus, an increase in the share of bus travel from 57% to 80% leads to a saving of 11 million tonnes of oil. The other advantages are a 54% reduction in total vehicles on the road, a 27% reduction in carbon dioxide emissions and a 33% reduction in aggregate road transport costs.

The increase in the number of buses required in the recommended scenario is 25,000 buses implying an additional investment of Rs 10,000 million. If we add 37 per cent for investments in infrastructure, the required investment is Rs 13,750 million (US $ 825.83 million) till the turn of the century. Assuming an average life time of 10 years, the total reduction in CO_2 emissions is 9.35 million tonnes of carbon, giving a specific cost of Rs 1470 (US $ 88.29) per tonne of carbon.

Rail Transport

At present, the only urban rail transport systems in India are in Bombay and Calcutta. Present plans project that these systems would provide a capacity of about 80 BPKM by year 2000. Urban rail transport systems lead to a reduction in energy consumption, and hence in CO_2 emissions. It is estimated that such a system in Delhi, costing Rs 26.8 billion (US $ 1.61 billion) would provide a capacity of 12.6 BPKM annually, resulting in net savings of about 1.13 MToe[13]. Consequently, CO_2 emissions would decrease by 0.96 MT of carbon per annum.

Providing urban rail transport in Madras and Delhi, and the seven cities in Table 4 with population between 2 and 8 million so as to move a total of 40 BPKM would cost about Rs 247.5 billion (US $ 14.86 billion), and result in CO_2 emission reduction of about 3.06 MT of carbon annually, and 122.4 MT of carbon over its 40 year life. It has been assumed that for Delhi and Madras the integrated metro system would cost Rs 45 billion (US $ 2.70 billion) each and move a total of 25 BPKMS. About 15 BPKMS would be moved in the seven other cities at the cost of Rs. 22.5 billion (US $ 1.35 billion) per city. Technology for the urban rail system would largely have to be imported: this includes locomotives, signaling and communication equipments, etc.

The modal split suggested by us is feasible if an imaginative policy for bus transportation providing for different types of services, like express, deluxe etc. to cater to different interests is implemented to wean away commuters from personalized transport to buses. A change in industrial policy in the automotive sector would also be needed. There will have to be an accelerated production of fuel efficient buses designed specifically for urban transport and a cut back on production of cars and two-wheelers.

Increasing the Rail Line Capacity

Increased rail track length (and accompanying increase in rolling stock) is aimed at ensuring that rail transport provides the same quality of service (in terms of speed and reliability) as does road transport. The rail freight transport service is expected to increase to 370 billion T-km by year 2000, and the road transport service to 570 billion T-km under the BAU scenario. With specific energy consumptions of 8 and 21 Toe per million T-km for the rail and road sectors respectively, the annual energy demand for freight transport in year 2000 would be about 15 million Toe, and CO_2 emissions would be approximately 12.7 million tonnes of carbon. In order to reduce the energy consumption and CO_2

emissions by one-thirds, an additional 380 billion T-km of rail capacity would have to be provided. Assuming that completely new track and rolling stock are required to meet the demand of 380 billion T-km, the total investments between now and year 2000 is approximately Rs 540 billion (US $ 32.43 billion) based on estimates extrapolated from the Corporate Plan of the Railways[14]. This would result in CO_2 emission reductions of 4.2 million tonnes of carbon per year.

We assume the life of the entire system to be 35 years. Thus an investment of Rs. 540 billion will result in saving 147 million tonnes of carbon over 35 years giving a specific abatement cost of Rs 3673.5 (US $ 220.63) tonne of carbon.

The above plan can be implemented as infrastructure to develop this additional capacity is or can be made available indigenously. The main constraint towards the enhancement of line capacity has been, and continues to be, the lack of financial resources.

International funding for meeting the cost of this incremental addition presents a peculiar problem. The projects are economically viable, i.e., an adequate rate of return will be generated, but the income (as well as much of the investment) will be in local currency. Given the unfavourable balance of payments position, and the precarious situation of foreign exchange reserves, it is open to question whether other sectors of the economy can generate adequate foreign exchange to service this debt.

Agricultural Sector

The problems that lead to low energy efficiency in this sector and the low rate of adoption of energy conservation measures suggested by the Inter Ministerial Working Group[3] largely hold true even today. The major reason for the lack of success of these measures is the lack of financial incentives to carry them out. As long as electricity tariffs to agriculture are subsidized, or based only on connected load, there is no incentive to farmers to install energy-efficient pumpsets, or to enhance their energy efficiency by retrofits. The setting of energy-related tariffs may by themselves, lead to a substantial decrease in electricity consumption - as much as 15% - without any other inputs. On the other hand, without restructuring the tariffs, large inputs could well lead to negligible savings.

There are about 8.5[27] million electrical pumpsets used in the agricultural sector, which on a nationwide basis, consume approximately 34 TWh (assuming 4000 kWh of electricity consumption per pumpset) electricity every year. It is estimated that complete rectification of these sets would reduce electricity consumption by about 50%[15]. The cost of rectification per set is approximately Rs. 10,000 (US $ 600.6) at 1990 prices. (Rs 8700 in 1987 prices[15]).

If the existing 8.5 million pumpsets were rectified investments required would be Rs 85 billion (US $ 5.1 billion). This would result in electricity savings of 17 TWh per year. Current T&D losses at 23% imply a saving of 15.47 TWh of coal based power generation. This would reduce carbon dioxide emissions by 5.06 million tonnes of carbon per annum.

Assuming an average life time of 10 years after rectification, total CO_2 saved would be 50.6 MT of carbon, giving a specific cost Rs 1679.84 (US $ 100.89) per tonne of carbon.

Domestic Sector

The domestic sector energy conservation potential was not addressed by the Inter-Ministerial Working Group. However, this is a particularly important sector from the perspective of energy efficiency improvements.

Biomass Utilization

The most detailed estimates of biomass utilization in the domestic sector were made in a 1978-79 NCAER survey[17]. These are summarized in the Table 6 along with estimates of future demand.

Table 6 : Demand for Traditional Biofuels in 2004/05

(million tonnes)

Source	**Population (million)**	**Fuelwood**	**Dungcake**	**Agricultural Waste**
NCAER[+,17]	641	95.5 (79.3)	71.7 (66.7)	30.6 (29.5)
WGEP[18]	-	61.3	33.6	18.9
ABE[2]	1046	312.0	207.0	94.0
EDSG[19]	1040	258.9 (187.0)	150.5 (132.2)	77.0 (71.8)
TEESE[*,20]		63.4	82.2	42.9
NCA[o,21]	-	150	-	-

Note: The numbers in brackets indicate estimates of rural energy demand.

+ These were consumption levels in 1978-79.

* The estimates are for the year 2005 from an optimization model. o The estimates are for the year 2000.

Assumptions Made in Various Studies

Working Group on Energy Policy[18] (WGEP)

a) Total household energy consumption norm is 0.4 tonnes of coal replacement (tcr) per capita per annum in urban areas and 0.38 tcr per capita per annum in rural areas

b) The use of commercial energy will increase to such an extent that the consumption of non-commercial fuel for cooking will be reduced to about 70 per cent of households in the rural areas, and 10.8 per cent households in urban areas in the year 2000.

c) The allocation of non-commercial fuels among fuelwood, agricultural residues, and dungcake is assumed to be in the ratio of 65:20:15.

Advisory Board on Energy[2] (ABE)

a) Total household energy consumption norm is 650 kcal per capita per day.

b) NCAER 1978/79 pattern of fuel consumption will be valid for 2004/05 also.

Energy Demand Screening Group[19] (EDSG)

a) The average useful heat consumption
= 650 kcal per capita per day for urban population
= 520 kcal per capita per day for rural population

b) Stove efficiency is 8 per cent.

c) NCAER pattern of fuel consumption will be valid for 2004/05.

TERI Energy Economy Simulation Evaluation Model (TEESE)

a) Fuelwood demand is fixed at the level of its consumption estimated for 1984-85.

b) Dungcakes availability is determined within the model as a function of the optimal number of draught cattle and a fixed number of milch cattle.

In the context of strategies for limiting CO_2 emissions from India, strategies to reduce demand for woody biomass play an important role. In this context the role of the programmes to promote biomass stoves becomes significant.

The current National Programme on Improved Chulhas (NPIC) has a target of 1.827 million stoves for 1990-91 at a financial outlay of Rs 125 million (US $ 7.51 million). It is estimated that approximately 65% of installed improved chulhas are used, and that these result in a 25% reduction in wood consumed that is about 0.23 tonnes of wood annually[22] for each chulha. An outlay of Rs 125 million would therefore results in the saving of 0.27 MT of wood annually, or a reduction in CO_2 emissions of 0.12 MT of carbon per annum.

We assume that 2 million improved chulhas are installed every year, for the next 10 years, at a total investment of Rs 1370 million (US $ 82.28 million). It is estimated that 79 per cent would be clay stoves. The life of a metal stove is 10 years and that of a clay stove is 3 years. Thus total carbon saved through the installation of 20 million cookstoves is 6 MT of carbon and the specific abatement cost is Rs. 228 (US $ 14) per tonne of carbon.

It is obvious that this strategy alone is not adequate to limit and improve the role of biomass fuels in cooking. A more comprehensive, enduse based planning approach using the following strategies in the domestic sector may contribute in some measure towards limiting CO_2 emissions from India the household sector :

1) More rapid and effective promotion of biomass based improved cooking stoves and biogas plants.
2) In the long term, biofuels should be processed to obtain better quality fuels with higher efficiency.
3) Implementation of area based cooking energy plans to substitute biomass with better quality fuels. For example,
   - Piped natural gas supply to the domestic sector near natural gas rich areas like the north-east,
   - Increased use of coal briquettes or coal gas mixture in the coal belt,
   - Sewage gas in urban areas.

Lighting

The current stock of electric lamps in India is about 600 million, including 400 million incandescents and 200 fluorescents. Incandescent lamps convert about 4% of the input electricity into light, while the conversion in fluorescents is about 10%. Compact fluorescents are currently not manufactured in India, but cost about Rs.250 (US $ 15.02) each, have a rating of 16 W, and last more than 8 years. Tube fluorescents have a rating of 40 W and last for 4 years. Incandescents last about a year, and have an average rating of about 60W. The replacement costs (per annum) of incandescents and fluorescents are approximately the same, the main difference is in the cost of installations which are

Rs 12 and Rs 110 respectively. The life of these installations is about 10 years in each case.

If current trends continue the installed lamp stock in India would be about 1 billion in 2000, i.e., 600 million incandescents and 400 million fluorescents. We assume that approximately 50% of the 60W incandescents are replaceable by 40W fluorescents. The cost of this conversion would be about Rs 7.4 billion (US $ 0.44 billion), and the annual energy savings would be 12.5 TWh (with 1000 hours of use per annum). Assuming T&D losses of 23%, and coal-based generation to account for 70% of total generation, the reduction in coal based electricity generation would be about 11.36 TWh annually. This implies CO_2 emission reduction of 3.72 million tonnes of carbon annually or total CO_2 reduction of 37.2 MT of carbon. The specific investment cost of this strategy is Rs 199 (US $ 11.95) per tonne of carbon.

Alternatively, if 50% incandescents are replaced by compact fluorescents, the cost would be Rs 51 billion (US $ 3.06 billion), but energy savings would be 15.58 TWh, or 10.91 TWh of coal-based electricity. This implies annual CO_2 reduction of 3.57 MT of carbon or a total CO_2 reduction of 35.7 MT, giving a specific cost of RS 1429 (US $ 85.82) per tonne of carbon.

While undertaking the above analysis it has been assumed that the quality of power supply would improve sufficiently by 2000 to enable implementation of these options.

Deployment of Renewable Energy Technologies

In the future, with the growth in the demand for energy, judicious resource use will have to be the cornerstone of a sustainable development effort, in which renewable energy sources play an important role. Even at present costs there are many applications in which renewable energy technologies are cost effective in addition to being environmentally benign. In the power sector, for example, windfarm power generation competes favorably with the cost of coal thermal route to electrical power generation. There is, similarly, a large potential for solar energy applications. Though solar energy applications are likely to be more cost effective in the medium temperature (100-150^{o}C) range, there are a whole range of applications which may be cost effective in the coming decade. These can have a significant effect on the reduction of fossil fuel consumption.

On the basis of projected installations of renewable energy sources, the potential CO_2 savings (based on emissions from coal-based TPS generating equivalent electricity) are summarized in Table 7.

Table 7 : Proposed Plans for Renewable Energy Utilization in India by 2001 AD

	Proposed Installed Capacity*	Budgetary Requirement (in Million Rs	US $)	Reduction in CO_2 Emissions over life (Million Tonnes Carbon)	Life time Assumed (in years)
Biogas Plants	12 (M#)	106750	6411	18.4	10
Solar Thermal System	20 (MTCR)	30500	1832	96	10
Power from Biomass	6000 MW	80000	4805	128 9	15
Power from Wind	5000 MW	75000	4505	43.0	20
Power from Small Hydro	2000 MW	40000	2402	51.0	30
Energy from Sewage Sludge	50 MW	1250	75	1 43	20
Energy from Distillery	140 MW	488	29	4 01	20
Energy from Municipal Solid	160 MW	5333	320	4.58	10
Photovoltaic pumps	15 MW	1563	94	1 07	25
Windpumps	50 MW	910	55	0.26	15
Power from solar systems	2000 MW	60000	3604	5.73	10

* Source: Energy 2001: Perspective Plan (for) Non-conventional Energy Sources, Department of Non-conventional Energy Sources (DNES), Govt. of India, 1987.

Considering by the financial constraints and current financial allocations, it seems unlikely that the requisite funding for these proposals will be forthcoming.

A more rational approach to planning for the energy sector requires consideration of the services provided by energy rather than energy per se. Often referred to as 'end use' planning, this method permits an analysis of the different energy conversion routes to meet energy end uses, permits the utilization of higher efficiency energy conversion paths for satisfying these end uses, allows a possible change to thermodynamically suitable fuel mix for different end uses, and can lead to energy policies which may result in a significant delinking of growth of energy consumption from development. Moreover, the end use approach, in conjunction with the actual cost of delivered energy, leads to a realistic assessment of the cost effectiveness of different source-technology-end use combinations from the viewpoint of society.

Availability of technology for meeting these diverse end uses is not the main problem. In India today the list of available innovative technologies based on renewable energy sources is impressive. Some of these have been discussed and many others can be listed. The major problem lies with the low priority attached to the renewable energy sector and the lack of funds earmarked for the utilization of these energy resources. For example, in the Seventh Plan period while the power sector received over Rs.3,42,700 million, the total allocation to the renewable energy sector was Rs.5,200 million, i.e., about 1.52% of the outlay for the power sector.

It would, however, be misleading to give the impression that all the renewable energy technologies have achieved the level of maturity or sophistication that is associated with the conventional routes to energy conversion. Here also, part of the reason can be attributed to the lack of funding for research and development in renewable energy technologies. Therefore, the question of resource mobilization for development of non-conventional forms of energy is critical to the whole programme in this area.

Afforestation

The Government of India has been striving to meet the stated objective of afforesting 33% of India's land area - about 328.8 million hectares (Mha). The annual planned and achieved afforestation and outlay are given in Table 8. Principally, land availability has been the major constraint in afforestation programmes.

Table 8

Year		1985/86	1986/87	1987/88	1988/89
I. Afforestation/ Tree planting (in million ha.)					
Targets	:	1.45	1.71	1.79	2.00
Performance	:	1.51	1.76	1.77	2.12
Achievement	:	104.1%	102.9%	98.0%	106%
II. Expenditure in crore of Rs.					
Outlays	:	384.94	492.48	540.83	620.48
Actuals	:	398.84	455.08	477.46	N.A.

Source : 25

The total area under forest cover decreased from 64.2 Mha in 1985 to 64.0 Mha in 1987, as indicated by satellite imagery (reconciled with ground data) with a minimum resolution of 25 ha[25]. Consequently, deforestation, as measured by satellite imagery, is of the order of 47500 ha per year. The biggest reason for deforestation is grazing, lopping, and firewood collection.

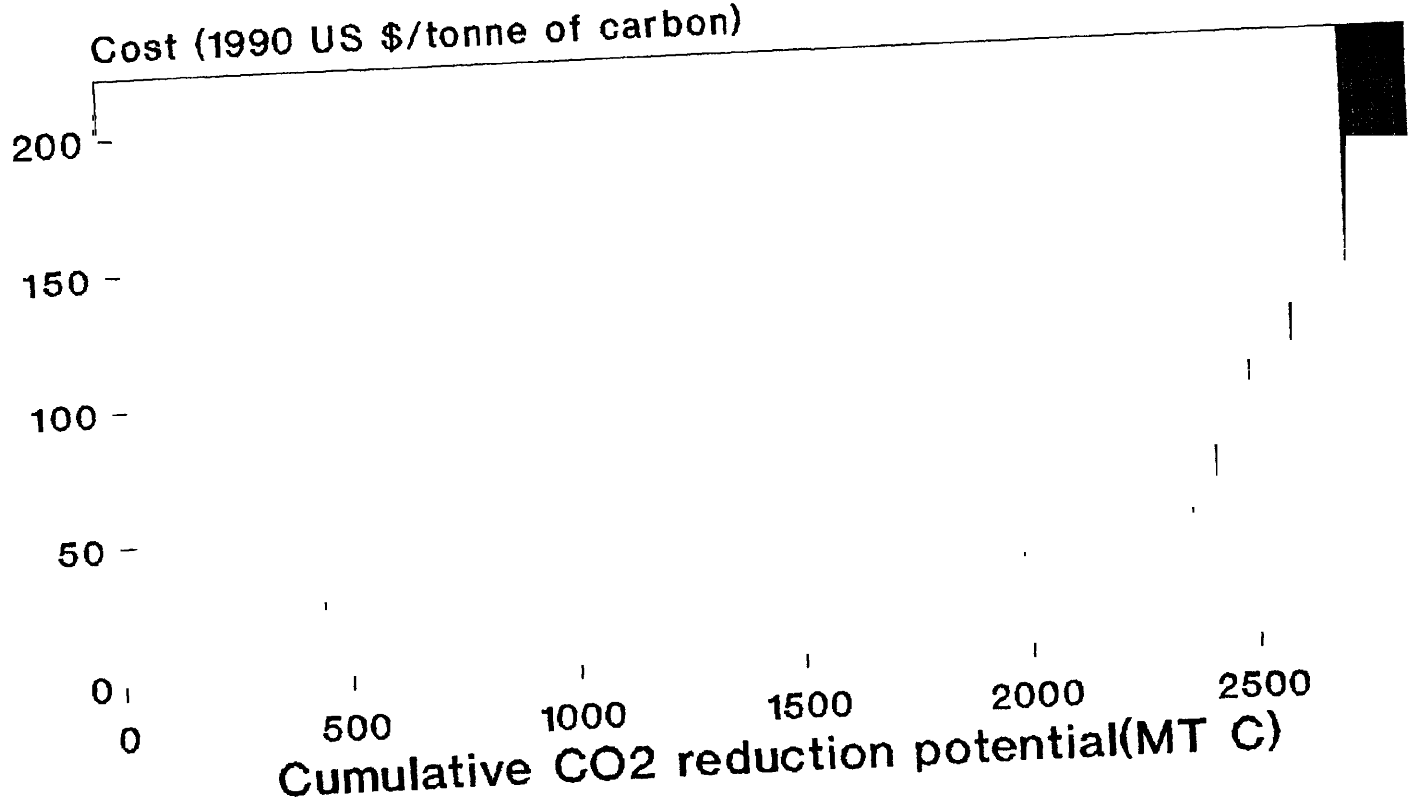
Afforestation through social forestry programs was of the order of 2 Mha in 1988-89. Most of these plantations are either in small woodlots which are less than 25 ha in area, or in strip plantations along canals, roads and railway lines. Neither of these plantations are visible through satellite imagery, and therefore could not have figured in the forest area computations. The area for single row plantations (along roadsides and canals) has been worked out on the basis of 2,000 plants per hectare. It should be pointed out that 2 Mha is not the actual area under afforestation but is notional. Most of the land where afforestation work has been done continues to be under grazing and other uses. The actual extent of plantation is well below the targets shown to have been achieved. We assume a 50% survival rate in social forestry plantations.

If the stated objective of foresting one-third of India's land area is to be achieved by 2000, 3.5 Mha per annum of afforestation are required over the next 10 years. Assuming a 50% survival rate, afforestation of 70 Mha over the decade would be required to fix roughly the same amount of carbon.

The average cost of afforestation is Rs 10,000 (US $ 600.6) per hectare. Therefore, the total investment works out to be Rs 700 billion (US $ 42.04 billion). Given a 50% survival rate, a growing wood stock of 65 cubic metres per hectare (which is the average for Indian forests today : Source 25), a biomass multiplier of 2, a wood density of 0.75 tonnes per cubicmetre and a carbon content of 45% for wood and biomass, the total carbon fixed is calculated to be 1.54 billion tonnes (over 35 years). The specific abatement cost is thus Rs. 455 (US $ 27.3) per tonne of carbon.

If afforestation is required to be done for CO_2 assimilation, the tree cover once created must be maintained. Unfortunately in the present planting programmes there is an undue emphasis on meeting the demand for fodder and fuel. The plantations created under the previous five-year plans have mostly been used up and they do not, therefore, contribute to CO_2 assimilation. These however, prevent deforesation or combustion of fossil fuels which would have taken place if wood from these plantations were not available. If plantations are desired to be carried out for CO_2 assimilation then afforestation must be followed with a good system of management so that the vegetal cover once created stays on the ground. Fortunately, trees keep increasing in crown size. Consequently, the CO_2 assimilation per tree increases with age upto maturity of the tree. A system can, therefore, be devised that afforestation can be used simultaneously for wood production as well as CO_2 assimiliation. This, however, will need a very good system of forest management. Mere afforestation and using up of the biomass so produced will not help in CO_2 assimilation.

Cost curve for energy related carbon dioxide emission reduction options



Emission reduction potential is the
total carbon saved over the life of
the option (in million tonnes of C)

APPENDIX I

IDENTIFICATION AND QUANTIFICATION OF ENERGY CONSERVATION MEASURES BY THE INTER MINISTERIAL WORKING GROUP, 1983

A. INDUSTRY SECTOR

Sl. No.	Recommendation	Saving Expected		Investment (in Rs., Crores)	Remarks
		In Million Tonnes of Coal Equivalent Per Annum	In Rs , Crores Per Annum		
Short Term Measures					
i.	Implementation of good keeping measures	7.1	616	400	House keeping measures include tuning of combustion equipments, proper maintenance of energy consuming equipments, condensate recovery insulation, etc.
ii.	Training of industrial personnel in energy				
iii.	Introduction of system of energy audit.				
Medium Term Measures					
iv.	Installation of waste heat recovery systems	8.9	772	1200	Investment figures indicated have to be borne by industry and government, the major portion being met by the industry
v.	Replacement of old inefficient boilers by high efficiency boilers				
vi.	Introduction of instrumentation and control systems				
vii.	Adoption of better technological innovations like ceramic fibers low excess air burners variable speed drives, etc.				
Long Term Measures					
viii.	Introduction of Co-generation systems	6.2	537	2000	
ix.	Adoption of newer energy efficient technologies.				
x.	Introducing computers for process control on real time basis				
	Total	22.2	1925	3600	

B. TRANSPORT SECTOR

Sl. No	Recommendation	Saving Expected		Investment (in Rs., Crores)	Remarks
		In Million Tonnes of Coal Equivalent Per Annum	In Rs., Crores Per Annum		
Short Term Measures					
i.	Accelerating the national programme on education campaign for users of road transport	1.68	240	200	
ii.	Enforcing speed limits and abolishing octroi checkposts	0.73	105	30	
iii	Emulating the concept of model depots in State Transport Undertaking	0 21	30	60	
Medium Term Measures					
iv	Adoption of energy efficient technology for new heavy vehicles, automobiles and 2/3 wheelers	a) 1 05 b) 0.31	150 90	300 200	a) For heavy vehicles b) For automobiles and 2/3 wheelers
v.	Formulating and implementing a plan for upgrading the quality of road surfaces	1.05	150	100	The investment has to be incurred on a recurring basis every year
	Total		765	890	

C. AGRICULTURAL PUMPSETS

Sl. No.	Recommendation	Saving Expected		Investment (in Rs., Crores)	Remarks
		In Million Tonnes of Coal Equivalent Per Annum	In Rs., Crores Per Annum		
Short Term Measures					
i.	Initiating of national education and awareness programme on energy conservation in lift irrigation pumpsets			100	
ii.	Organizing programme for remedying the installation defects in the existing pumpsets	1 6	340	400	Installation defects like undersizing of suction and delivery pipes, high resistance foot valves, etc.
Medium Term Measures					
iii.	Technology development for high efficiency pumpsets and oil engines and introducing the same for new pumpsets	0 33	70	150	
	Total	1 93	410	650	

APPENDIX II

Calculation of investments required for reducing T & D losses

(i) To reduce technical losses from 15% to 13% by the end of the 8th FYP period, the investment requirement is given by the following empirical relationship :

$$\left(\left(\frac{15}{13}\right)^{1/2} - 1 \right) * 55000 = \text{Rs } 4079 \text{ crores}$$
$$= \text{Rs } 40800 \text{ million (say)}$$

(ii) Similarly, to further reduce technical losses from 13% to 11% over 1995-2000, the investment required is :

$$\left(\left(\frac{13}{11}\right)^{1/2} - 1 \right) * (550{,}000 + 40800 + 335000)$$
$$= \text{Rs } 80{,}650 \text{ million}$$

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CHAPTER 6: COUNTRY PAPER THE ISLAMIC REPUBLIC OF IRAN

Ali A. Mojtahed - Shabestari
The Institute for Political and International Studies (IPIS)
and
F. Shariat, M. Ghiassedin
University of Tehran- Faculty of Health

EXECUTIVE SUMMARY

Total energy consumption in Iran in 1989, was 68.24 Million Tonnes Oil Equivalent (MTOE). Considering enormous gas and oil resources, about 95% of consumed energy was provided by liquid and gas fossil fuels. The total carbon dioxide emission from fossil fuels was about 39.2 million tonnes of carbon.

Sharing the international concern over global climate change, and having suffered directly from the pollution, in the Persian Gulf region caused by the burning of Kuwaiti oil wells, Iran has already undertaken serious steps to curb CO_2 emissions (i.e. in using oil and natural gas which are cleaner fuels in power generation) and is also examining the potential for further limitation in the other major energy consuming sectors as well as afforestation.

In this paper, after looking at the energy consumption in Iran, present day CO_2 emissions estimation, then projection of energy supply and demand for year 2000 are touched upon. At the end, technologies to curb CO_2 emission and preliminary estimates of cost of abatement measures are studied. Table 14 indicates the potential, the investment cost and cost for some of the limitation options.

Energy Consumption and Greenhouse Gas Emissions in Iran

Introduction

Iran, with an area of 1648,000 Km^2 is situated in the Middle East between Caspian Sea and the Persian Gulf. Different regions in Iran have diverse climate, varying between semi-tropical and cold. Iran is considered as an agricultural country with oil production, but because of elevated mountains and desert areas, cultivation occurs only in 14.4% of its area.

Population growth in our country, has been accompanied by relative economic development and growth of consumption of fossil fuels and electric-utilities. Emissions of gases in the atmosphere resulting from fuel burning, especially CO_2, and also CFCs from cooling and refrigerating equipments have been unavoidable.

Population

According to the last population census, Iran's population was 58,400,000 persons. 51.65% of them are living in rural areas and 48.35% in urban areas. At the present time, population growth, all over the country, is 2.9% while this growth was 3.2%, between 1976 and 1986.

Per capita income

Iran's per capita income is $ 1186 (based on exchange rate of US$ 1 equal to 600 Rials) and 520.00 (on the basis of floating exchange rate of US $).

Energy Consumption in Iran

Considering the enormous gas and oil resources, about 95% of consumed energy is provided by liquid and gas fossil fuel.

Other energy resources, according to degree of importance, are electricity, coal, charcoal and biomass.

Charcoal and biomass are insignificant in comparison to other energy resources.

Oil Products

Iran is the third largest oil exporter in the world, and is the second with respect to reserved resources of oil and natural gas.

Fuel oils are used in the form of gasoline, kerosene, diesel oil and residual oil. Table 1 indicates the mean consumption of fossil fuel oils in Iran from 1989 to 1991.

Table 1 : Consumption of Petroleum Products from 1989 to 1990 in Iran (Mt)

Type	1989	1990	1991	Growth Percentage
Gasoline	6.13	6.42	6.71	9.5
Kerosene	8.38	8.67	10.01*	19.5
Diesel oil	17.41	18.39	19.21	10.4
Residual oil	11.44	11.68	11.92	4.0
LPG	2.32	2.32	2.29	2.0
+Others **	2.83	2.77	2.84	0.6

* Eight percent had been used for petrochemical industries.
** Jet fuel, solvents, asphalt and motor oil

Electricity

Electricity generation in Iran is either in the form of hydroelectric power which is almost considered to be free of environmental pollution or by burning petroleum products. There is no power generation in Iran using coal as a fuel. Table 2 shows consumption of petroleum products for energy generation from 1967 to 1989. This Table indicates that growth rates of per capita consumption are in the order of 1.9, 6.88 and 8.88 for diesel oil, residual oil and natural gas respectively.

Table 2 : Power Plants Petroleum Consumption

Year	Population	Diesel Oil		Residual Oil		Natural Gas	
		Total ML	Per Capita L	Total ML	Per Capita L	Total MM^3	Per Capita M^3
1967	25788722	136	5.27	311	12.06	13	0 50
1977	33708744	990	29.36	1145	33.96	1533	45 48
1987	49445010	1480	29 93	3559	71.98	5451	110.24
1989	54345246	1259	23.17	4101	75.46	6863	126 28

Generated electricity provides 20% of total energy consumption.

Table 3 shows electricity generated from various systems in million tons of oil equivalent.

Table 3 : Total Electricity Generated in Iran (1989) MTOE

Hydro	1.8
Steam	7.4
Natural Gas	3.39
Diesel	0.52
Total Power Type	13.11

Coal

Coal is only used for industries. By the order of magnitude of consumption of coal in Iran would be the steel industry, smelting and sugar producing industries. Table 4 and 5 show the amount of production and consumption of coal in Iran during 1989.

Table 4 : Production of Coal in Iran 1989

District	Mt	MTOE
Kerman	0.698	0.456
Central Alborz	0.168	0.109
East Alborz	0.221	0.144
West Alborz	0.052	0.034
Total	1.159	0.758

Table 5 : Consumption of Coal in Iran 1989

Industry	Mt	MTOE
Steel Factory	2.0	1.300
Sugar & Smelting	0.1	0.065
Others	0.2	0.13
Total	2.3	1.5

Natural Gas

Iran possesses the second richest natural gas resources in the world. Domestic and industrial use of natural gas is always increasing. New or developing power generating plants have been planned for gas or furnace fuel consumption. The rate of consumption is estimated according to the use of energy resources. Natural gas production and consumption data are shown in Table 6 & 7 respectively.

Approximately 80% of produced natural gas is exported.

Table 6 : Natural Gas Production in Iran

Year		MM^3	MTOE
1989	Heavy	69350	45.99
	Light	59020	35.77
	Total	123370	81.76
1990	Heavy	72635	47.45
	Light	56210	36.50
	Total	128845	83.95
1991	Heavy	80300	53.29
	Light	64970	43.80
	Total	145270	97.09

Table 7 : Consumption of natural gas in Iran

Year	MM^3	MTOE
1989	21978	14.23
1990	24478	16.06
1991	30038	19.70

Organic Materials

Sewage sludge

The amount of sludge generated is 1705280 tons BOD per year. Sewage sludge generates a total of 0.13 MTOE per year leading to 0.11 Mt of elemental carbon emissions.

Firewood, Agricultural Residue & Animal Manure

Animal manure, firewood and agricultural residue in 1989 constitute 0.33 MTOE. According to statistics released from the Ministry of Agriculture, there are 127 x 10^6 domestic animals as sheep units. This will result in the production of 1668780 tons BOD (Biochemical Oxygen Demand) per year.

Sectorwise Energy Consumption

Electricity consumption in different sectors is given in Table 8 for the year 1989.

Table 8 : Sectorwise electricity consumption (1989)

Type	MTOE	%
Agriculture	0.4	8.4
Industry	1.02	21.2
General Use	1.32	27.2
Domestic	1.22	39.5
Others	0.18	3.7
Total	4.84	100

Overall energy consumption in different sectors for the year 1989 is shown in Table 9.

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* **Note** The term 'sheep unit' is used by the Ministry of Agriculture for animals bigger than or smaller than sheep; for instance 1 cow = 10 sheep units, and 1 goat = 0.6 sheep units.

Table 9 : Overall energy consumption in 1989 in MTOE

Type	Electricity	Oil	Hydro	Coal	NG	Total
Agriculture	0.27	3.50	--	--	--	3.77
Industry	1.01	7.64	--	0.67	2.73	12.05
Domestic & Commercial **	2.22	12.73	--	0.50	4.15	19.60
Power Generation	0.48	4.79	1.6	--	6.00	12.40
Transportation	--	12.30	--	--	---	12.30
Oil Refineries	0.05	2.13	--	--	0.35	2.54
Others	0.10	0.15	--	0.33	5.0	5.58
Total	13.11	43.24	--	1.5	14.23	68.24

** Domestic & Commercial - This includes Household, Business and Offices, public services.

It can be concluded from Table 9 that the domestic and commercial sectors are the highest energy users. However, the percentage share of each sector is as follows:

	Percent
Agriculture	5.5
Industry	17.6
Domestic & Commercial	28.7
Power Generation	18.2
Transportation	18.1
Oil refineries	3.7
Other (including injection of natural gas in oil fields)	8.2

CO_2 Emission Estimation

Emission of CO_2 is from fossil fuel burning as well as deforestation. The amount of fossil fuel consumed in Iran as oil products, natural gas and coal are 43.24, 14.23, and 1.5 MTOE respectively.

Deforestation

According to the latest statistics there are about 12.4 million hectares of jungles in Iran, out of which 1.3 million hectares are in the Caspian area in a fairly good condition. But 11.1 million hectares located in the southern part of Zagross mountains are not in good shape, in other words, they are sporadic or ruined. In a period of two decades (1965-1985) about one million hectares, mostly from Caspian forest, have been destroyed by misharvesting.

The estimate of grasslands is about 90 million hectares, out of which 16 million hectares are poor, 60 million are bushy and in fair condition and only 14 million hectares are grassy and in good condition. About 100,000 hectares of grass lands are converted to desert each year. It is estimated that about 5 million ton elemental carbon equivalent of CO_2 will be added to the atmosphere as a result of deforestation and desertification. Table 10 shows estimate of fuelwise CO_2 emission in 1989 as million ton elemental carbon.

Table 10 : Fuelwise CO_2 Emission in Iran 1989 (million ton element carbon)

	MTOE	CO_2
Oil	43.24	28.1
Natural gas	14.23	9.39
Coal	1.5	0.99
Animal manure & Firewood & Crop residue	0.33	0.21
Sludge	0.13	0.11
Total	59.43	38.80

The CO_2 emission factors used are from IIASA (1988) and Rotty and Masters (1985). The calculations of CO_2 emissions from oil are given as an example.

$$\frac{43.24 \times 0.85 \times 0.918 \times 120}{144} = 28.1$$

Table 11 : Sectorwise CO_2 Emission in Iran (1989) Million Tons of Elemental Carbon

Sector	CO_2
Agriculture	2.31
Industries	8.93
Domestic & Commercial	11.48
Power Generation	7.92
Transportation	8.12
Biomass * & Sludge	0.3
Deforestation	5.74**

* Biomass includes animal manure and firewood and crop residues
** Loss of CO_2 absorption

Projection of Energy Demand and Supply for the Year 2000

Considering the first and second plans for economic development of Iran, oil and gas production as well as industry, mining and agriculture are under rapid development. The energy production and consumption for the year 2000 has been foreseen as in Table 12.

Table 12 : Energy Supply for the year 2000 (MTOE)

Energy form	Supply	Demand
Crude oil	229.52	81.43
LPG	7.59	7.59
NG	132.38	76.97
Coal	1.91	3
Electricity	33.61	27.39

Sectorwise projection of energy demand by the year 2000 is shown in Table 13.

Table 13 : Projection of Sectoral Energy Demand and Supply for the year 2000 as MTOE

Sector	Demand	Supply
Agriculture	9.95	10.40
Industry	39.50	40.26
Domestic & Commercial	51.74	54.09
Power Generation	32.73 *	33.6
Transportation	33.9	32.4

* By the year 2000 four nuclear power generators are going to join the country's network system and will generate 3000 MW equal to 2.11 MTOE.

Note : Energy demand projections by Ministry of Power. The underlying assumption for population growth is 2.9%.

Technologies to Limit CO_2 Emissions

Reducing CO_2 emissions into the atmosphere is one of the top priorities of the Iranian Government. This could be achieved either by adopting energy efficiency measures or carbon fixing measures like afforestation

Afforestation

Afforestation is supported strongly by the government and it is planned to develop 100,000 hectares of jungle each year. Besides producing active farm lands and grasslands is in progress.

Power Generation

Power plants in Iran are designed for both residual oil and natural gas. By changing systems the total emission of CO_2 and other air pollutants from oil will decrease considerably. It must be noted that coal is not being used at all in power generation due to it being a relatively less clean fuel apart from the resource endowment of Iran.

Table 14 . Cost of some Projected Plans through Year 2000 in US $

	Output	Investment	Operation & Maintenance	Life
Oil and Gas Production		3050	76.25	
Oil and Gas Processed		4450	133 5	
Gas Network		1200	18	
Petrochemical		1500	52 5	
Petrochemical Completion Project		900	90	
Steam Power Generation		1130	16 95	
Hydropower	14 MTOE	500*	10	
Nuclear Power	# 4640 MW			30
Solar Power	***	...	.....	...
Wind generation	***	...	.....	...
Afforestation				

* Rough estimate

# In the year 2000, the share of nuclear energy in power generation, would be 20% of the total amount generated.

*** Solar energy production and utilization of wind energy is still under study. Hence extent of its production in 2000 is not known at this juncture.

Development in Oil Industry Through Year 2000

The most important development aim in Iran is to increase oil production as follows:

1. Increase exploration of new fields for increasing the country's income.
2. Provide the share of energy needed for long term industrial development.
3. Provide hydrocarbons needed for industries and particularly for the petro-chemical industry.
4. Increase income through export of oil production.
5. Decentralization of industries for the benefit of different parts of the country.
6. Improvement in quality of oil production.
7. To save oil product consumption and to maintain balance of oil consumption among different economic activities and increasing the efficiency of oil usage by employing better technologies.
8. Improve quality of products for meeting environmental standards.

To fulfill these projections during first five year development plan, it is estimated that an investment of about 11,100 million US$ for oil and gas development projects will be needed. The major plans regarding these activities are:

Name of Project	Total Investment Five Year First Plan (million US $)	Expected Savings (million US $)
Oil and Gas Production	3050	156×10^3
Production and Distribution of Oil and Gas	4450	1100
Gas Transfer and Distribution	1500	350
Petro-chemical Products	2785	1200

estimated to be 15,000,000 journeys per day. Increasing bus fleets for major cities is also planned. Replacing LPG instead of gasoline for public buses is another project for pollution reduction which has already been started for Tehran, Shiraz and Mashad.

Since the most CO_2 emission comes from gasoline burning (4.5 MTOE) an improvement in public transportation and roads will decrease CO_2 emissions, these general activities are expected to reduce about 5% of overall CO_2 production. Seasonal time changing (beginning of spring & autumn) has resulted in energy saving of 2540 MW/h equal to 2.01 MTOE.

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CHAPTER 7 : JAPAN COUNTRY PAPER

Naoki Matsuo

The Institute of Energy Economics

Tokyo, Japan

Executive Summary

Energy related emissions of carbon dioxide are an important cause for increasing concern over global climate change. As far as carbon dioxide emission abatement is concerned, Japan has achieved one of the highest levels of energy conservation among the developed countries.

In this paper, first, we show the present status and future outlook of Japan's CO_2 emissions using a model developed by the Institute of Energy Economics (IEE), Japan. Some scenarios are investigated with some assumptions. It concludes that the stabilization of CO_2 emissions at the 1989 level in and after 2010 causes a 1% point lower economic growth, and at the level of 2000 in and after 2000 does not affect the economic growth of Japan so much.

Second, an action programme of the Japanese government to arrest global warming is introduced. Measures to limit CO_2 emissions and to enhance CO_2 sinks are presented.

Third, energy conservation measures and new energy technologies in Japan are presented. Here we also discuss the importance of energy conservation in Japan and in other parts of the world.

Fourth, we see some bottom-up cost estimating examples to limit CO_2 emissions in Japan. In some cases, comparisons with other OECD countries show that energy saving costs in Japan are much higher than those in other parts of the world.

Fifth, we present an evaluation which shows the CO_2 reduction potential and cost in other countries in case they install facilities of the same efficiency as in Japan today.

This highlights the importance of Japan's international cooperation in the field of energy saving technologies.

In this paper, we sometimes emphasize the comparison between Japan and other countries. As a member of Asia, Japan can and must transfer energy saving and less polluting technologies to her neighbour countries. Her role in Asia at present is to help other countries in the region to reduce the energy/CO_2 intensities of their respective economies.

Introduction

Past trends in energy and CO_2 emissions in Japan

Carbon dioxide (CO_2) emissions in Japan stood at approximately 40.8 million tonnes (in carbon equivalent) around 1953 --- the year in which Japan's economic activities regained the prewar level. As consumption of energy increased along with rapid economic expansion in subsequent years, CO_2 emissions also increased as shown in Table 1. During the 20-year period 1953-1973 (the year of the first oil crisis), Japan's GNP grew at an average annual rate of 9.0%, primary energy demand and CO_2 emissions increasing at 9.3% and 9.9% a year, respectively. Between 1973-85, during which the two oil crises took place, GNP growth rate fell by more than half, to 4.0% a year, and the rate of increase in primary energy demand dropped to 0.8% due to industrial restructuring and stepped-up efforts to conserve energy. CO_2 emissions declined at an average annual rate of 0.1% largely as a result of the introduction of nuclear energy as well as liquefied natural gas (LNG).

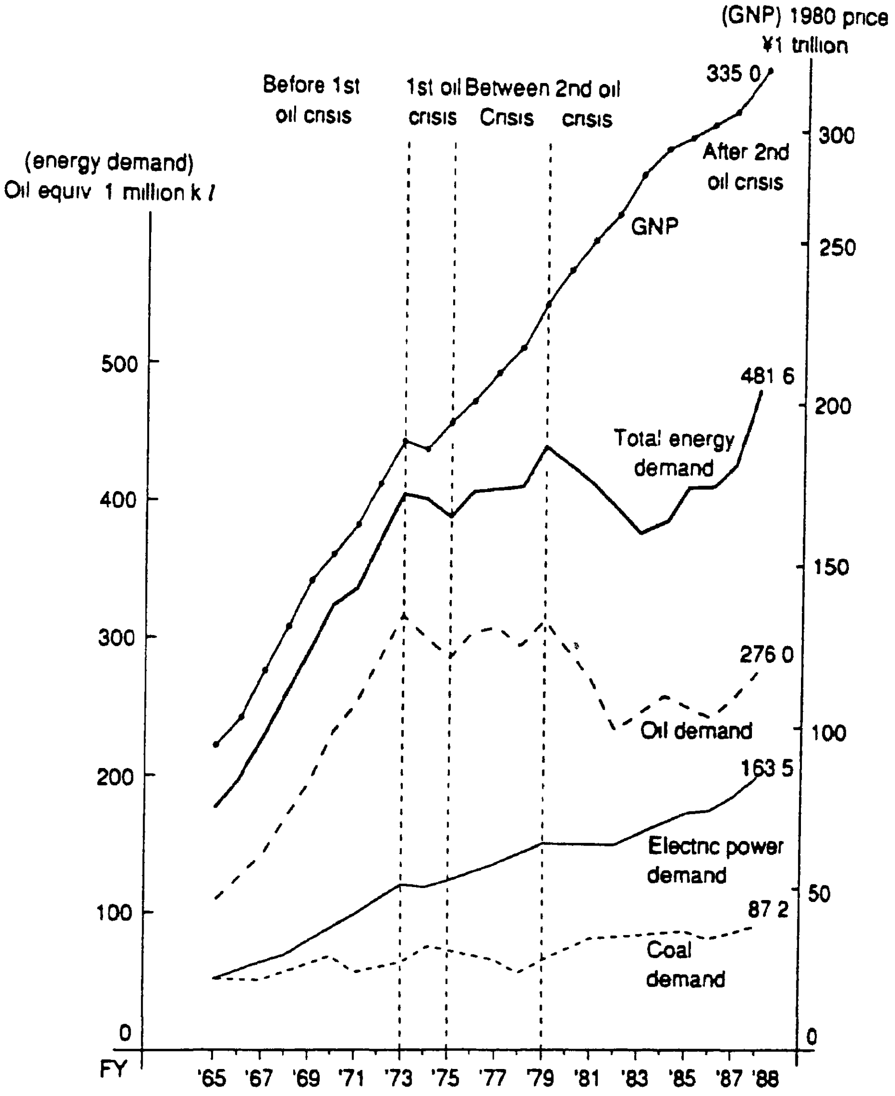
Recent years, especially in and after 1987, have witnessed economic expansion, including the recovery of production by energy-intensive industries such as iron & steel and chemicals. Energy demand has increased as rapidly as GNP (real terms), partly the result of slowed-down energy conservation efforts due to low energy prices. CO_2 emissions increased accordingly, reaching an estimated total of 300 million tonnes (in carbon equivalent) in fiscal 1989. Recent trends in energy demand and GNP are depicted in Figure 1.

Table 1 : GNP, Energy demand and CO_2 emissions in Japan FY 1953-1988

Item	1953	1965	1973	1985	1988	1989	Avg. ann. rate of increase (%) '73/'53	'85/'73	'88/'85	'88/'53
CO_2 emissions (Mt-C)	40.8	114.4	271.2	267.8	290.2	301.6	9.9	-0.1	2.7	5.8
Primary energy demand (Mtoe)	60.9	152.3	358.4	393.4	432.1	447.6	9.3	0.8	3.2	5.8
GNP (¥ tril.) (1985 prices)	32.8	89.7	184.6	294.0	335.0	388.2	9.0	4.0	4.4	6.9
CO_2/energy (Mt-C/Mtoe)	0.669	0.751	0.757	0.681	0.672	0.674	0.6	-0.9	-0.4	0.0
Energy/GNP (Mtoe/¥ tril.)	1.855	1.699	1.942	1.338	1.290	1.153	0.2	-3.1	-1.2	-1.0

Source : IEE/The Energy Data & Modeling Center

Figure 1 : Trends in Energy Demand and GNP



Current CO_2 emissions in Japan

Here we summarize the current (FY 1989) CO_2 emissions from the energy sector in Japan. Table 2 shows the CO_2 emission matrix as fuel-wise and sector-wise. We do not have any data showing the net deforestation contributions, unfortunately. However, it may be little in comparison to the CO_2 emitted by fossil fuel combustion in Japan.

Table 2 : CO_2 Emissions in Japan (10^6 ton-C; FY 1989)

	Coal	Petroleum	Gas	Total
Energy consumption(T)	62.3	125.2	8.9	196.4
Industrial sector(T)	61.4	45.6	2.3	109.4
Agriculture/Forest	0.0	4.9	0.0	4.9
Fisheries	0.0	3.4	0.0	3.4
Mining	0.0	0.3	0.0	0.3
Construction	0.0	3.9	0.0	3.9
Manufacturing(T)	61.4	33.1	2.3	96.9
Food	0.0	2.0	0.3	2.3
Fiber	0.0	2.3	0.1	2.4
Paper/Pulp	1.1	2.8	0.1	4.5
Chemical Ind	1.7	8.6	0.6	10.9
Cement	15.1	3.4	0.1	18.6
Steel	41.5	2.6	0.4	44.6
non-Steel metal	0.4	0.9	0.1	1.5
Mashine	0.7	1.5	0.6	2.8
Others	0.8	9.0	0.0	9.8
Resid./Comm. sector(T)	0.9	25.8	6.5	33.2
Residential	0.0	13.5	4.6	18.1
Commercial	0.9	12.2	2.0	15.1
Transportation sector(T)	0.0	53.8	0.0	53.8
Energy Conversion(T)	43.0	42.8	19.4	105.2
Electricity(business)	26.9	33.6	18.8	79.3
Electricity(personal)	10.3	7.1	0.0	17.5
Heat supply conversion	0.1	0.0	0.1	0.1
Self-consumption	5.7	2.0	0.5	8.3
TOTAL	105.3	168.0	28.3	301.6

Source The Institute of Energy Economics, Japan

More than half the emissions are from the combustion of petroleum, about a third is from coal and about 10% from natural gas. Almost a third comes from electricity generation and also from manufacturing industries. About 10% is from the residential/commercial sector, and about 20% is from the transport sector. Currently, the residential/commercial and transportation sector show rapid growing in terms of energy consumption : industrial sector grows 3.1%/year, residential/commercial sector grows 4.5%/year and transportation sector grows 4.4%/year (1989-1990).

Outline of this paper

To limit CO_2 emissions in the future, Japan must develop and induce extremely advanced technology. Information on potentials and costs for each technology in 2000/2010, and the corresponding CO_2 emission abatement, is at best limited and uncertain. Thus, although the aim of the study is to evaluate strategies to limit CO_2 emissions in terms of costs and potentials, we are able to show only some cost estimating examples for Japan. Instead, the following exercise has been carried out in this paper :

1) Japan's present status of CO_2 emissions is shown as sector-wise and fuel-wise.

2) Japan's energy supply/demand outlook in 2000 and 2010 projected by using simulation model of IEE is presented.

2-1) First, in the standard scenario (in which no special supplementary measures are taken), corresponding CO_2 emissions are estimated.

2-2) Next, in simulation studies aimed at stabilizing CO_2 emissions, analyses are made on six scenarios introduced in accordance with the extent of CO_2 stabilization (specifying at what levels and by when). These six scenarios call for stabilization of CO_2 emissions at the fiscal 1989 level --- in and after 2010 and 2000 --- and stabilization of CO_2 emissions at the 2000 level in and after 2000 in the standard scenario. Improvement in energy consumption efficiency, extent of introduction of new energy sources, adjustments to economic activities and energy price levels and combinations of these factors are considered in each of these scenarios.

2-3) Magnitudes of GNP losses (or slow-down in the economic growth rate in real terms) are estimated for each scenario.

2-4) Finally, we present a list of near term feasible measures to limit CO_2 emissions, as identified by the Government of Japan in the "Action Program to Arrest Global Warming".

3) Action program to arrest global warming of Japanese government is introduced. Measures to limit CO_2 emissions and enhance CO_2 sinks are presented.

4) Energy conservation and new energy technologies in Japan are listed.

4-1) Factor analysis of CO_2 emissions of Japan and other parts of the world is shown.

4-2) The two projects of the government concerning new kinds of energy and energy conservation technologies are introduced.

4-3) Energy conservation technologies are shown here.

5) We see some cost estimating examples to save CO_2 emissions in Japan. There remains some problems to estimate the total cost, however, bottom-up method is applied on the part of the residential/commercial sector, industrial sector and energy conversion sector as examples.

6) Here we discuss the roles of technologies and Japan's international cooperation. CO_2 reduction potential and its cost are estimated using two kinds of methods in the case that other countries will install the facilities as in Japan at present.

7) The discussions follows.

Also energy/environmental policy of Japanese government and its key issues are introduced in Appendix A.

Japan's energy supply/demand outlook and CO_2 emissions[1]

Major assumptions used in the standard case

i. Economic growth rate (in real terms) assumed in this analysis are 3.7%/year during the period 1988-2000; 2.9%/year during the period 2000-2010; and 3.3%/year for 1988-2010, i.e., slowly decreasing rate is assumed.

ii. Industrial restructuring to increase the value added to products and to service-oriented industries :

IIP = Index of Industrial production

	1988	2000	2010
Machinery industry's IIP* (1980=100)	122	206	294
Iron/steel industry's IIP (1980=100)	105	119	125
(Crude steel production, mil.tons)	(106)	(90)	(70)
Floor space for business	Projected to increase at 1.5%/year during the period 1988-2010		

iii. Crude oil prices and yen's exchange rate vs. U.S. dollar are:

	2000	2010
Crude oil prices ($/bbl):		
In real terms	25	30
(In nominal terms)	(35)	(58)
Yen's exchange rate vs. U.S. dollar	110	100

iv. Taking account of the delay in securing sites for construction of nuclear power plants due to the anti-nuclear movement, it is assumed that the plan by the Electric Utility Industry Council for expanding nuclear power plant capacity will be slowed by around 10% by 2000 and by around 20% by 2010 --- 46 million kW and 58 million kW in 2000 and 2010, respectively.

2.2 Major results of forecasting in the standard case

i. Primary energy supply :

Primary energy supply is forecast to increase at 2.4%/year during the period 1988-2000, 1.2%/year between 2000-2010, and 1.8%/year during 1988-2010 (see Table 3).

Table 3 : Primary energy supply --- Standard Case
(in actual units)

Energy	Unit	Actual (1988)	Standard Case	
			2000	2010
Coal	mil.t	115	132	132
Oil	mil.kl	263	348	383
Natural gas	mil.t	33	50	62
Hydropower	bil.kWh	92	101.3	109.7
	(mil.kW)	(20.29)	(25.70)	(27.80)
Nuclear power	bil.kWh	178.7	302.2	381.1
	(mil.kW)	(28.87)	(46.0)	(58.0)
Geothermal	mil.kl	0.38	1.19	1.62
New energy sources & others	mil.kl	6.17	7.24	10.38
Total	mil.kl	467	621	697

(% Share)

Energy	Actual (1988)	Standard Case	
		2000	2010
Coal	18.7%	16.1%	14.3%
Oil	56.4	56.0	54.9
Natural gas	9.9	11.2	12.5
Hydropower	4.8	4.0	3.8
Nuclear power	9.3	11.8	13.3
Geothermal	0.1	0.2	0.2
New energy sources & others	1.4	1.4	1.5
Total	100.0	100.0	100.0

Note : Figures do not add up to totals, since coke exports are excluded from the total

(Average annual rate of growth, %/year)

Energy	Standard case		
	2000/ 1988	2010/ 2000	2010/ 1988
Coal	1.1	0.0	0.6
Oil	2.3	1.0	1.7
Natural gas	3.5	2.2	2.9
Hydropower	0.8	0.8	0.8
Nuclear power	4.5	2.3	3.5
Geothermal	10.0	3.2	6.9
New energy sources & others	1.3	3.7	2.4
Average	2.4	1.2	1.8
GNP growth rate, %/year	3.70	2.90	3.34
Energy/GNP elasticity	0.65	0.40	0.55

Sources: The Institute of Energy Economics, Japan.

ii. Rate of energy conservation:

Energy consumption per unit of GNP is forecast to decline 14% during the period 1988-2000, and 27% during the period 1988-2010.

Primary energy demand-GNP elasticity is forecast to be 0.65 during the period 1988-2000, 0.40 during the period 2000-2010 and 0.55 during the period 1988-2010 as shown in Table 4.

Table 4: Outlook for GNP, Energy consumption per unit of GNP, elasticity, CO_2 emissions Standard case

Energy	Actual		Forecast		Avg. ann rate of growth			
	1975	1988	2000	2010	1988/ 1975	2000/ 1988	2010/ 2000	2010/ 1988
GNP (¥ tril. in 1980 prices)	190.875	333 832	516 262	687 098	4.4	3.7	2.9	3.3
Energy/GNP (toe/¥ bil.)	1.800	1.294	1.112	0.939	-2.5	-1.3	-1.7	-1.4
GNP elásticity		1988/ 1975	2000/ 1988	2010/ 2000				
	--	0.41	0.65	0.40				0 55
CO_2 emissions (Mt-C)	255.0	290.2	376 9	409 6	1.0	2 2	0 8	1.6
CO_2/Energy (t-C/toe)	0.742	0.672	0.657	0.635	-0 8	-0 2	-0 3	-0.3

Sources. The Institute of Energy Economics, Japan

iii. Reliance on oil:

Japan's reliance on oil is projected to decline only slightly through 2010, from 56.4% in fiscal 1988 to 56.0% in 2000 to 54.9% in 2010 (see Table 3). iv.

Reliance on nuclear power:

Nuclear power generating capacity is forecast to increase from the current 30 million kW to 46 million kW by 2000 and 58 million kW by 2010 (Table 6). In actuality, however, these plans are expected to be delayed to a considerable extent due to the anticipated difficulty in siting new nuclear power plants.

Nuclear power as a percentage of primary energy supply is forecast to increase steadily from the 9.3% in fiscal 1988 to 11.8% and 13.3% by 2000 and 2010 respectively (Table 3). As a percentage of total power generating capacity, it is projected to rise from the 27.0% in fiscal 1988 to 31.8% by 2000 and 33.0% by 2010.

v. Introduction of new energy sources:

Supply of new energy sources as a percentage of total primary energy supply is projected to increase only slightly from the 1.4% in fiscal 1988 to 1.5% by 2010 (refer Table 3).

vi. Final energy demand:

It is forecast that final energy demand will increase at 2.2%/year during the period 1988-2000, 1.0%/year during the period 2000-2010, and 1.6%/year during the period 1988-2010 as shown in Table 5.

Final energy demand in the industrial sector as a percentage of total final energy demand is projected to decline from the 53.2% in fiscal 1988 to 45.5% by 2000 and 41.9% by 2010.

Meanwhile, in the residential/commercial sectors final energy demand is projected to increase its share of total final energy demand from the 24.6% in fiscal 1988 to 30.3% and 31.8% in 2000 and 2010 respectively. In the commercial sector, in particular, it is expected to show a sharp increase from the 10.9% in fiscal 1988 to 14.8% by 2000 and to 15.4% by 2010, and that in the transport sector is projected to increase substantially from the 22.3% in fiscal 1988 to 24.2% by fiscal 2000 and to 26.3% by 2010.

Table 5 : Outlook for final energy demand by economic sector --- standard case

(Mtoe, %)

Energy	Actual		Forecast		Avg ann.rate of growth				Percentage share			
	1975	1988	2000	2010	1988/ 1975	2000/ 1988	2010/ 2000	2010/ 1988	1975	1988	2000	2010
Industrial sector	155.2	160.1	177.5	180.3	0.2	0.9	0.2	0.5	61.8	53.2	45.5	41.9
Excl.non-energy	148.9	151.7	166.7	168.1	0.1	0.8	0.1	0.5	59.3	50.4	42.8	39.0
Non-energy	6.3	8.3	10.8	12.2	2.2	2.2	1.2	1.8	2.5	2.8	2.8	2.8
Residential/commercial sectors	49.6	73.9	118.0	136.9	3.1	4.0	1.5	2.8	19.7	24.6	30.3	31.8
Residential	25.6	41.1	60.2	70.6	3.7	3.2	1.6	2.5	10.2	13.6	15.4	16.4
Commercial	24.0	32.9	57.8	66.3	2.4	4.8	1.4	3.2	9.6	10.9	14.8	15.4
Transportation sector	46.3	67.0	94.3	113.3	2.9	2.9	1.9	2.4	18.4	22.3	24.2	26.3
Passengers	23.8	38.1	56.5	69.2	3.7	3.3	2.0	2.8	9.5	12.7	14.5	16.1
Commodities	22.5	28.9	37.8	44.1	2.0	2.3	1.6	1.9	9.0	9.6	9.7	10.3
TOTAL	251.1	301.0	389.9	430.6	1.4	2.2	1.0	1.6	100.0	100.0	100.0	100.0

Sources: The Institute of Energy Economics, Japan.

vii. CO_2 emissions:

CO_2 emissions are projected to rise from the 290.2 million tonnes (in carbon equivalent) in fiscal 1988, to 376.9 million tonnes (a 29.9% increase per 12 years) by 2000 and to 409.6 million tonnes (a 41.1% increase per 22 years) by 2010 (see Table 4).

Table 6 : Outlook for electric power generation (by electric utilities) and power generating capacity

(1) Electric power generation

(Mtoe, %)

Energy	Actual 1988	Forecast		Avg.ann.rate of growth(%)			Percentage share		
		2000	2010	2000/ 1988	2010/ 2000	2010/ 1988	Actual 1978	2000	2010
Nuclear power	177.6	301.2	380.0	4.5	2.4	3.5	27.0	31.8	33.0
Hydropower (published statistics)	88.6						12.9	10.1	9.0
Conventional (Energy Balance Table)	84.8	95.6	104.0	1.0	0.8	0.9			
Pumped up	3.8								
Coal-fired power	63.6	138.1	163.4	6.7	1.7	4.4	9.7	14.6	14.2
Oil (& others*)-fired power	194.5	195.1	220.2	0.0	1.2	0.6	29.6	20.6	19.1
Natural gas-fired power	141.4	213.6	256.9	3.5	1.9	2.8	21.5	22.5	22.3
Geothermal power	1.1	4.5	6.3	12.6	3.4	8.3	0.2	0.5	0.5
New power sources	0.0	2.0	22.6	--	27.5	-	0.0	0.2	2.0
Total (published statistics)	666.8						100.0	100.0	100.0
Latest (Energy Balance Table)	657.7	947.5	1150.8	3.1	2.0	2.6			
Pumped-up input	9.1								
Pumped-up loss	-5.2								
Thermal power generation efficiency (kcal/kWh)							38.44	38.86	39.10

* Included dual- and multi-fuels in and after 2000

Sources: The Institute of Energy Economics, Japan.

Table 6 (cont'd) Outlook for electric power generation (by electric utilities) and power generating capacity --- standard case

(ii) Power generation capacity (million kW)

Energy	Actual 1988	Forecast 2000	Forecast 2010	Avg ann rate of growth 2000/1988	Avg ann rate of growth 2010/2000	Avg ann rate of growth 2010/1988
Nuclear power	28.7	46.0	58.0	4.0	2.3	3.2
Hydropower (published statistics)	36.13					
Conventional	19.13	24.0	26.0	1.9	0.8	1.4
Pumped up	17.0					
Coal-fired power	11.12	32.0	37.0	9.2	1.5	5.6
Oil (& others*)-fired power	55.63	56.0	56.0	0.1	0.0	0.0
Natural gas-fired power	33.06	49.0	65.0	3.3	2.9	3.1
Geothermal power	0.18	1.0	1.0	15.4	0.0	8.1
New power sources	0.0	0.0	5.0			
Total	164.82					
Excl.pumped-up	147.82	208.0	248.0	2.9	1.8	2.4

* Included dual- and multi-fuels in and after 2000.

Sources : Institute of Energy Economics, Japan

Framework of simulation for stabilization of CO_2 emissions

Scenarios listed below are considered for stabilization of CO_2 emissions at the level of those in fiscal 1989 in Japan (around 300 million tonnes in carbon equivalent) by (i) 2010 and (ii) 2000, and for stabilization of CO_2 emissions at the level of those in 2000 in the standard case in and after 2000. A combination of basic assumptions such as energy consumption efficiency, the extent of introduction of new energy sources, the level of economic activities and energy prices are varied. The case of high energy prices is assumed to have the same effect as that of introducing a tax (carbon tax or its equivalent) aimed at restricting CO_2 emissions.

Standard case

Scenario 1:

Stabilization of CO_2 emissions at the fiscal 1989 level is achieved by 2010, assuming standard energy prices.

Scenario 2:

Stabilization of CO_2 emissions at the fiscal 1989 level is achieved by 2010, assuming high energy prices.

Scenario 3:

Stabilization of CO_2 emissions at the fiscal 1989 level is achieved by 2000, assuming standard energy prices.

Scenario 4:

Stabilization of CO_2 emissions at the fiscal 1989 level is achieved by 2000, assuming high energy prices.

Scenario 5:

CO_2 emissions are stabilized in and after 2000 at the 2000 level in the standard case, due primarily to energy conservation measures.

Scenario 6:

A case in which CO_2 emissions are stabilized in and after 2000 at the 2000 level in the standard case, due primarily to promotion of nuclear power generation.

Further Assumptions:

A. Improvement of energy consumption efficiency --- applies to all scenarios for stabilization of CO_2 emissions:

- Industrial sector: approximately 0.5 percentage point/year is assumed.
- Commercial sector: approximately 0.5 percentage point/year is assumed.
- Residential sector: energy conservation as shown below is assumed vis-a-vis the standard case by improvement of efficiency of household appliances

(Mtoe)	1988	2000	2010	00/88	10/00	10/88
Standard case	41.1	60.2	70.6	3.2	1.6	2.5
Acc. energy conservation		57.0	63.9	2.8	1.1	2.0

- Transportation sector: additional energy conservation as shown below is assumed vis-a-vis the standard case by improvement of automotive fuel efficiency.

(Mtoe)	1988	2000	2010	00/88	10/00	10/88
Standard case	67.0	94.3	113.3	2.9	1.9	2.4
Acc. energy conservation		84.6	92.3	2.0	0.9	1.5

These assumptions lead to the following final energy demand reduction in 2000 (from 389.9 to 366.1 Mtoe) and in 2010 (from 389.9 to 366.1 Mtoe).

Energy Consumption Results:

	1988	2000	2010	00/88	10/00	10/88
GNP (¥ tril.)	333.8	516.3	687.1	3.7	2.9	3.3
Final energy demand (Mtoe)						
Standard case	301.0	389.9	430.6	2.2	1.0	1.6
TLFD*/GNP (a)	0.902	0.755	0.627			
Acc. energy conservation		366.1	381.9	1.6	0.4	1.1
TLFD*/GNP (b)		0.709	0.556			
Energy conservation rate (1-b/0.902)x100		21.4	38.4			

(Notes)

Mtoe = Oil equivalent in million tonnes
TLFD = Total final energy demand
b = Final energy demand/GNP

B. Stepped-up introduction of new energy sources

--- applies to all scenarios:

A breakthrough is envisaged for introduction of new energy sources by varying the rate of reduction in new energy costs and the rate of increase in production of energy units, thus shortening the period for making new energy sources competitive with existing energy sources.

In introducing new energy sources, two models are assumed in this study --- a model for new energy cost, and a model for introduction of new energy sources. The former model is used to estimate the cost of new energy sources and determine the year in which new energy sources can compete with existing energy sources, while the latter model is used to estimate a market share of new energy sources in each year and to determine volumes of new energy sources to be introduced by multiplying those shares by total energy demand. Assumptions are varied in the new energy cost model.

Extent of reduction in CO_2 emissions due to stepped-up introduction of new energy sources by comparison of the following two cases:

(Mt-C)	1988	2000	2010	00/88	10/00
Acc. energy conservation case	290.2	350.2	354.7	1.6	0.1
Stepped-up new energy introduction case		350.0	352.7	1.6	0.1

Because of its exponential growth, a little difference can be seen in 2000 and 2010. It will be remarkable in 2030.

Table 7 : Projection of Primary Energy Prices - nominal (real)

				Average annual rate of growth (%)	
	1988	2000	2010	00/88	10/00
Standard prices:					
Crude oil ($/bbl)	15	35	58	7.4	5.2
(real)		(25)	(30)	(4.4)	(1.8)
Coal (¥/Mcal)	0.9	1.4	1.9	3.45	3.5
(real for $ basis)				(1.0)	(1.0)
LNG (¥/Mcal)	1.6	2.6	4.0	4.2	4.2
(real for $ basis)				(1.8)	(1.7)
High prices					
Crude oil ($/bbl)	15	43	84	165	6.9
(real)		(30)	(43)	(63)	(3.9)
Coal (¥/Mcal)	0.9	1.7	2.8	5.35	5.2
(real for $ basis)				(2.6)	(3.1)
LNG (¥/Mcal)	1.6	2.7	4.9	4.7	5.9
(real for $ basis)				(2.0)	(3.8)
(CIF crude oil parity prices on heating value basis)					

Sources: The Institute of Energy Economics, Japan.

C. Energy prices

Standard and high energy prices are assumed, with the coal price assumed by adding an incremental crude oil price for high prices case to the standard coal price.

D. Economic activities level

GNP growth rates are adjusted in accordance with each case, adjusting production indices and materials production volumes by varying the growth rate of GNP.

Simulation for stabilization of CO_2 emissions and its implications

Our simulation studies for various scenarios, achieving the stabilization of CO_2 emissions at the level of around 300 million tonnes in carbon equivalent in fiscal 1989, in which no efforts were made to mitigate CO_2 emissions, by 2010 and 2000, have disclosed the following : (see also Table 8).

1) **Scenario 1 and 2**

To stabilize CO_2 emissions at the fiscal 1989 level in and after 2010, economic growth must be slowed down from 3.3%/year in the standard case to 2.3-2.5%/year, despite greater energy conservation and stepped-up introduction of new energy sources. GNP losses are estimated to total ¥ 51-67 trillion ($460-737 billion) in 2000 and ¥ 109-140 trillion ($1,000-1,270 billion) in 2010.

2) **Scenario 3 and 4**

GNP growth rate must be reduced from 3.7%/year --- the average annual rate of GNP growth during the period 1988-2000 in the standard case --- to around 2.0%/year. In these scenarios, GNP losses (vis-a-vis the standard case) are estimated to total ¥ 83-93 trillion ($730-850 billion) in 2000 and ¥ 160-170 trillion ($1,600-1,700 billion) in 2010.

3) **Scenarios 5 and 6**

To stabilize CO_2 emissions at the level of 2000 (estimated to be a 26% increase from the fiscal 1989 level in the standard case) in and after 2000, economic growth must be slowed by 0.4 percentage points from 2.9%/year (during the period 2000-2010) in the standard case to 2.5%/year, while vigorously accelerating energy conservation measures (Scenario 5). Alternatively, development of nuclear power must be carried out 10% ahead of the standard case, increasing the capacity of nuclear power generating capacity in 2010 from 58 million kW (standard case) to 64 million kW, with greater efforts to obtain public acceptance of nuclear power development. Economic growth will reduce by 0.3 percentage points from 2.9%/year (in the standard case) to 2.6%/year during the period 2000-2010 (Scenario 6).

Inferences

CO_2 emissions in Japan, if conventional policy measures are continued (standard case), are expected to increase 29.9% by 2000 and 41.4% 2010.

According to the energy supply and demand simulation studies (taking economic growth into account), if stabilization of CO_2 emissions at the fiscal 1989 level must be achieved in and after 2000, Japan's economic growth will slow down by about one-half, in addition to accelerated efforts toward energy conservation and introduction of new energy sources and higher energy prices.

Table 8: Comparison of scenarios
(in terms of average rate of change)
--- Economic growth, energy demand & CO_2 emissions

	Standard case	CO_2 stabilization by 2010		CO_2 stabilization by 2000		CO_2 stabilization in & after 2000	
		Std. prices (Scenario 1)	High prices (Scenario 2)	Std. prices (Scenario 3)	High prices (Scenario 4)	(Scenario 5)	(Scenario 6)
GNP							
2000/1988	3.70	2.50	2.80	2.00	2.20	3.70	3.70
2010/2000	2.90	2.00	2.20	2.00	2.00	2.50	2.60
2010/1988	3.34	2.27	2.53	2.00	2.11	3.15	3.20
Primary energy (E)							
2000/1988	2.40	1.35	1.36	1.03	0.99	2.39	2.39
2010/2000	1.17	0.27	0.17	0.23	0.04	0.51	0.80
2010/1988	1.84	0.86	0.82	0.66	0.56	1.54	1.67
Energy conservation (E/GNP)							
2000/1988	-1.26	-1.12	-1.40	-0.95	-1.18	-1.26	-1.26
2010/2000	-1.68	-1.70	-1.99	-1.74	-1.92	-1.94	-1.76
2010/1988	-1.45	-1.38	-1.67	-1.31	-1.52	-1.57	-1.49
Diversification away from fossil fuels (CO_2/E)							
2000/1988	-0.19	-0.46	-0.46	-0.54	-0.55	-0.20	-0.30
2010/2000	-0.33	-0.71	-0.74	-0.74	-0.81	-0.58	-0.69
2010/1988	-0.26	-0.58	-0.58	-0.63	-0.67	-0.37	-0.42
CO_2 emissions (Mt-C)							
1988	290.2	290.2	290.2	290.2	290.2	290.2	290.2
2000	376.9	322.5	323.1	307.3	305.9	376.4	376.4
2010	409.6	308.5	305.2	291.7	283.2	374.0	380.3

Source: The Institute of Energy Economics, Japan

Whether policies which would have such a large negative impact on GDP growth be politically acceptable remains an open question.

If stabilization of CO_2 emissions at the fiscal 1989 level is to be achieved in and after 2010, the economic growth rate must be reduced one percentage point, despite vigorous efforts towards energy conservation and the introduction of new energy sources.

Stabilization of CO_2 emissions at the level of 2000 in and after 2000, if carried out along with energy conservation efforts and promotion of nuclear power development, can be achieved without jeopardizing economic growth so much.

Action program to arrest global warming

In order to tackle the problem of rising CO_2 emissions, the Government of Japan has formulated an "Action Programme To Arrest Global Warming" spelling out near term feasible measures. This programme has the following targets :

a. Stabilization of per capita CO_2 emissions in the year 2000 and beyond at about the same level as in 1990.

b. Stabilization of the total amount of CO_2 emission in the year 2000 and beyond at about the same level as in 1990, through progress in the development of innovative technologies.

With respect to sinks of CO_2, the programme aims at the conservation and development of forests, and greenery in the urban areas of Japan.

In order to achieve these targets, measures recommended include a combination of restructuring of the economy and lifestyles.

Measures to limit CO_2 emissions

Formation of urban and regional structure with low CO_2 emissions

This is proposed to be achieved through the adoption of the following mitigating measures:

(1) The use of greenery to moderate high temperature in urban areas and by alleviating the heat-island phenomena in urban areas, thereby reducing the energy demand for air-conditioning.

(2) The adoption of insulation in dwellings and other buildings. In addition, the use of renewable energy, such as through solar water heater, passive solar energy systems and photovoltaic cells, should be promoted.

(3) Unused heat with low thermal energy from urban activities such as subway and sewage systems and thermal energy in river and sea water, should be used as thermal energy for air-conditioning through usage of heat pumps.

(4) Use of heat from incineration process of wastes and the utilization of energy from sewage sludge.

Formation of transport systems with low CO_2 emissions

Measures required include

(1) Reduction of CO_2 emissions from individual motor vehicles through (a) improved energy efficiency (b) use of energy with low CO_2 emissions and (c) mitigating traffic jams and insuring smooth trips by developing/improving ring roads and sophisticated traffic control systems.

(2) Shift to mass transit systems such as railways and buses for cargo and passenger transport, as well as development/improvement of appropriate information systems and terminal facilities.

Formation of production structure with low CO_2 emission

(1) For the **manufacturing sector**, measures include (a) improvement of combustion efficiency, (b) the introduction of processes which contribute to energy-saving, (c) more effective use of unused heat.

(2) **In agriculture, forestry and fisheries**, improved energy efficiency of farming machinery and fishing ships, and the use of renewable energy sources are suggested.

(3) In the **construction sector**, energy efficiency of construction machinery should be improved.

Formation of energy supply structure with low CO_2 emissions

This requires the adoption of the following measures :

(1) Use of energy with no/low CO_2 emission, such as nuclear energy, hydraulic, geothermal and solar power and natural gas.

(2) Introduction and development of combined-cycle power generation.

(3) Reduction of peak-hour demand and the storage of energy so as to smooth out electricity demand difference between different times of the day.

Realization of life styles with low CO_2 emissions

In order to realize life styles with low CO_2 emissions, various social systems should be reviewed and improved, and the environmental education should be further strengthened.

These measures include:

(1) New systems for the development and diffusion of easily recyclable and recycled products should be adopted.

(2) Products with low CO_2 emissions should be used.

(3) A daylight saving system should be adopted.

(4) At households and offices, adequate temperature in air-conditioning and heating, energy control systems household equipment and office automation devices with high energy efficiency should be brought into use.

Measures to enhance CO_2 sinks (forests and other greens)

These measures include:

(1) Adequate management and conservation of domestic forests

(2) Conservation and creation of greens in and around urban areas

(3) Rational use of timber resources

Japanese government's outlook of energy supply/demand to meet the above mentioned action program was published in June 1990. However, it is quite a tough target to achieve because of its high reliance on energy conservation and nuclear energy. Details are shown in Appendix A.

Energy conservation and new energy technologies in Japan

Factor Analysis of CO_2 Emissions in Japan and other countries[2]

As shown in Table 1 and Figure 1, Japan has developed a relatively low CO_2 emitting society after 1973 (First oil crisis) as compared to other developed countries. Here we show the factor-wise CO_2 change in Japan and other countries of the world in order to see this feature of Japan and her difference with the rest of the world.

CO_2 emissions are described as

$$CO_2 = (CO_2/\text{Energy}) \cdot (\text{Energy/GDP}) \cdot (\text{GDP/Population}) \cdot (\text{Population})$$

and its variation can be expressed as the summation of each factors:

$$\frac{d(CO_2)}{CO_2} = \frac{d(CO_2/\text{Energy})}{CO_2/\text{Energy}} + \frac{d(\text{Energy/GDP})}{\text{Energy/GDP}} + \frac{d(\text{GDP/Pop.})}{\text{GDP/Pop.}} + \frac{d(\text{Population})}{\text{Population}}$$

Each term can be interpreted as "fuel switching (carbon intensity) factor", "energy conservation (energy intensity) factor", "economic growth (economic intensity) factor" and "population growth (population intensity) factor", respectively. Factor analyses of Japan, developed countries, USSR/Eastern Europe and developing countries are depicted in Figure 2 - 5.

Figure 2 : Factor Changes in CO_2 Emissions : Japan

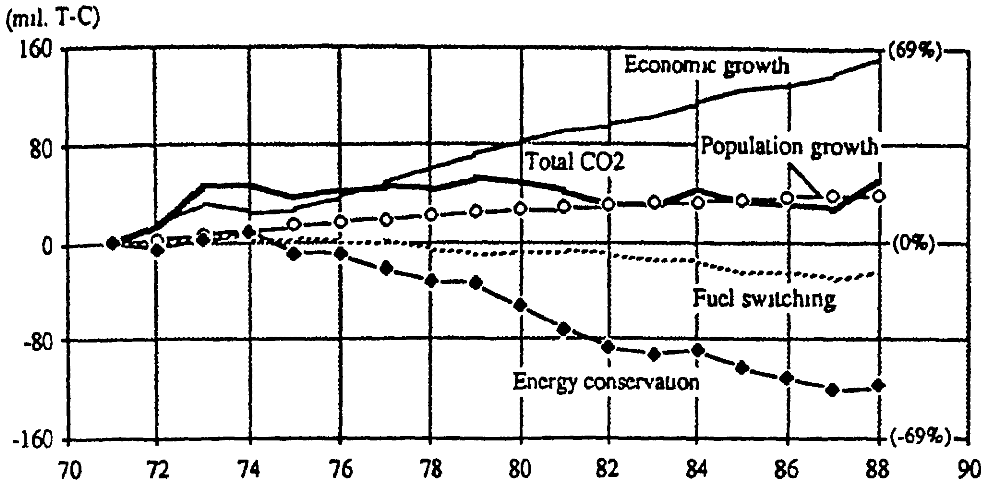


Figure 3 : Factor Changes in CO_2 Emissions : Industrial Area

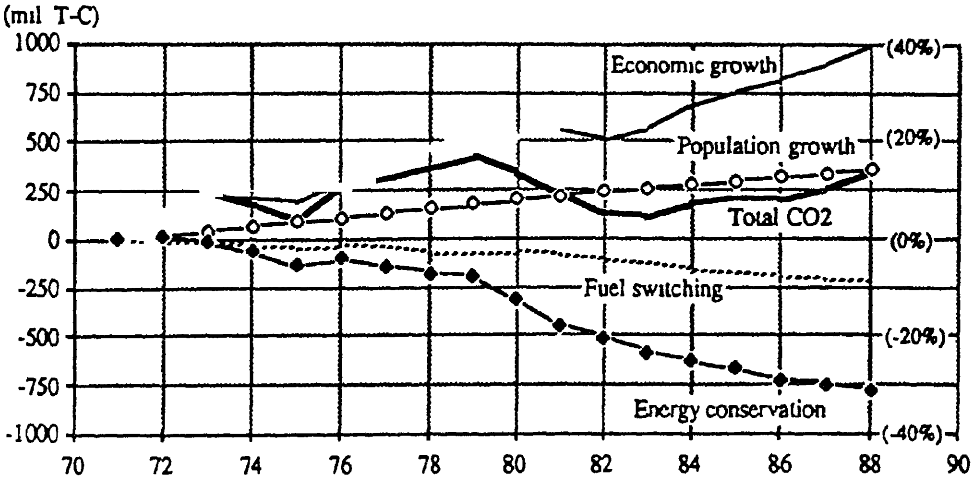


Figure 4 : Factor Changes in CO_2 Emissions : USSR/Eastern Europe

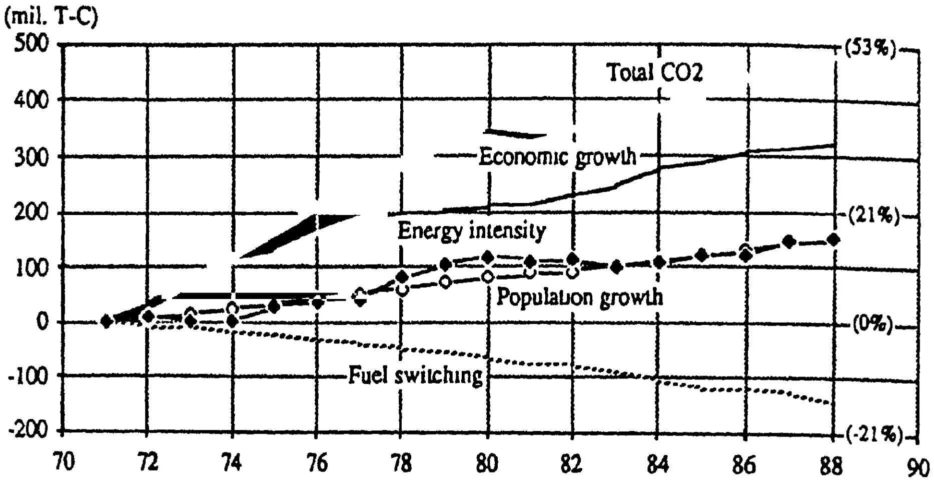
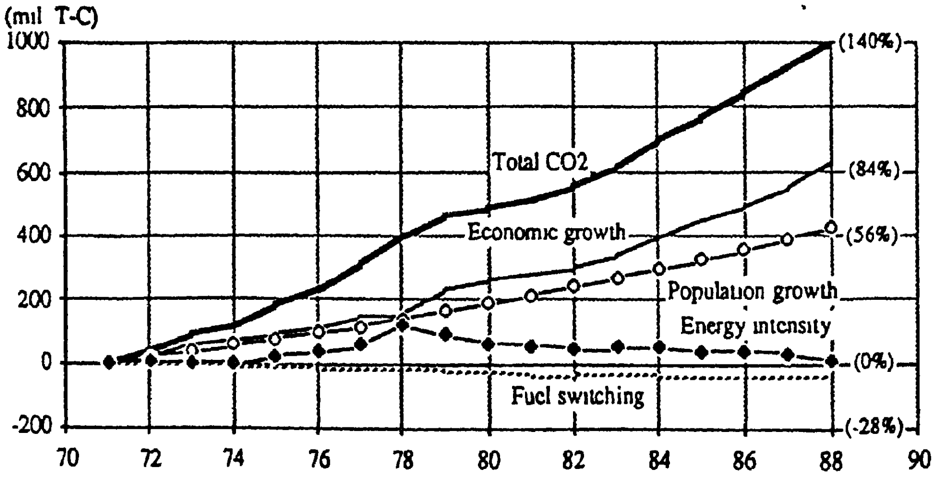


Figure 5 : Factor Changes in CO_2 Emissions : Developing Area



From these figures, we conclude that the energy conservation has contributed most in Japan and it is at a quite high level compared to other countries. Industrial areas shows the same tendency like Japan (increasing/decreasing rates are almost 2/3 of that of Japan). While in the USSR /Eastern Europe, negative energy conservation is remarkable because of their political problems. In the developing countries, it should be noted that population growth has contributed greatly to the growth of CO_2 emissions and there is almost no energy conservation. Their rapid growth of CO_2 emissions is remarkable and they will certainly be dominant emitters in the world in the near future.

Sunshine and Moonlight Project

As shown in the last section, energy conservation has played the most important role to reduce CO_2 emissions in Japan. Here we pay attention to its technological aspects in Japan.

The Japanese government (MITI; Ministry of International Trade and Industry) has promoted two projects which promote development of efficient technology for CO_2 reductions.

The Sunshine Project is aimed at the development of new energy alternative to petroleum and has been steadily promoted for 16 years. Major emphasis is on renewable energy sources such as solar energy (photovoltaic and thermal) and geothermal energy. New utilization of coal is also studied. Overview of the technologies is shown in Appendix B.

The Moonlight Project is for the development of technologies from the viewpoint of improving energy efficiency, utilizing wasted heat, etc. In promoting energy conservation policy, development of technologies is greatly expected in such fields as conversion, transportation, storage and consumption together with organizing legal measures for the rationalization of energy consumption and public enlightment of energy conservation ("the law concerning the rational use of energy" and economic incentives --- tax incentives and financial aid --- are now employed in Japan).

Energy Conservation Technologies

In the coming few decades, we will rely mostly on enérgy conservation in order to reduce CO_2 emissions. So here we list some technological aspects to slow down the energy consumption in Japan.

(1) Comprehensive/system technologies:

  i. Utilization of unused energy such as city waste heat.
  ii. Cascaded heat utilization system from power generation process.
  iii. Co-generation system as decentralized energy supply system.
  iv. Composite energy utilization system such as synthetic fuel made from methanol, ethanol, hydrogen, biomass, etc.

v. Recycling system of wastes produced as end products.

vi. City traffic system for improving energy efficiency of vehicles.

(2) Component technologies such as (a) combustion technology, (b) power generation and transmission technology, (c) heat utilization technology, (d) co-generation technology, (e) power conversion technology, (f) energy storage technology, (g) industrial process technology and (i) other technologies.

Past trend of energy conservation in major industries and technological aspects and prospects in Japan are collected in Appendix C.

Examples of cost estimation to save CO_2 emission

Problems in estimating total capital cost

There are some difficulties or problems to estimate the total cost in order to reduce CO_2 emissions in Japan.

First, as mentioned in the last sub-section and Appendix C, there are quite a lot of component technologies in Japan. And not so many cases are estimated carefully. Some examples are shown in the following sub-section.

Secondly, total investment cost is not expressed as a simple sum of each investment cost. Complex industrial transfer matrix should be applied to estimate the total cost and it might result in very different estimates. A comparison of micro-economic and macro-economic estimation is shown in the subsection titled Capital Costs Needed. Moreover, not only component technologies but also change of industrial structure, recycling of materials and integrated energy system have a big potential to save energy consumption.

Thirdly, it might be better to estimate the marginal cost instead of capital cost, although it is very difficult.

Cost Estimating Examples

As mentioned above, we cannot fully estimate the total capital cost in Japan; some examples are presented below.

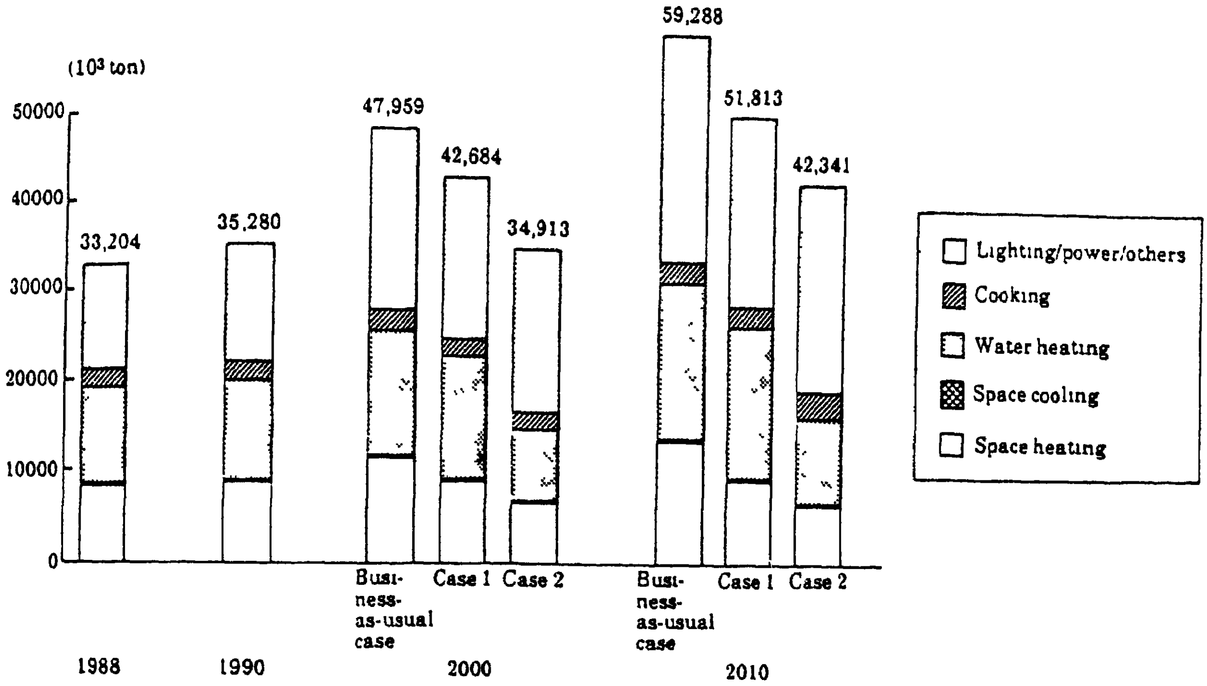
Residential/Commercial sector in Japan

Here we show T. Iguchi's paper as an example.[3] Figure 6 presents the estimated CO_2 emissions from residential sector in Japan. Table 9 and 10 show the incremental capital cost --- defined as the cost which is added to the normal cost in case that some energy conservation facilities are equipped --- and energy cost reductions, respectively.

Figure 7 is for the estimated CO_2 emissions from commercial sector. Table 11 and 12 also show the CO_2 reduction cost and reduced energy cost, respectively.

It should be noted that this estimation shows the reduced fuel cost be greater than incremental abatement cost.

Figure 6 : Estimated CO_2 Emissions Resulting From Residential Energy Consumption



(Note) Case 1 Improved insulated-structure case
Case 2 Conservation-technology strengthened case

Table 9 : CO_2 Reduction Cost (Residential Sector)

Applicable technology	Incremental cost (¥1 mil)		
	(1989-2000)	(2001-2010)	Total
(Improved insulated-structure case)			
Insulation of housing	1,577,700	4,214,300	5,792,000
Electric multi-functional heat pumps	234,500	16,900	281,400
Gross total			6,043,400
(Conservation-technology strengthened case)			
Solar water heaters	222,500	251,400	473,900
Passive solar housing	590,000	1,180,000	1,770,000
Electric multi-functional heat pumps	1,350,400	97,500	1,447,900
Gas engine heat pumps	1,584,900	114,400	1,699,300
Gross total			5,391,100

Table 10 : Conservation-Based Energy Cost Reductions (Residential Sector)

	1988-2010 Total energy use (10^6 Mcal)	*1 Conserved energy in volume (10^6 Mcal)	*1 Conserved energy in value (¥1 mil)
Business-as-usual case	12,091,291	–	–
Improved insulated-structure case	11,116,313	974,978	17,753,197
Conservation-technology strengthened case	9,208,881	2,882,410	35,817 939

Figure 7 : Estimated CO_2 Emissions Resulting from Commercial Energy Consumption

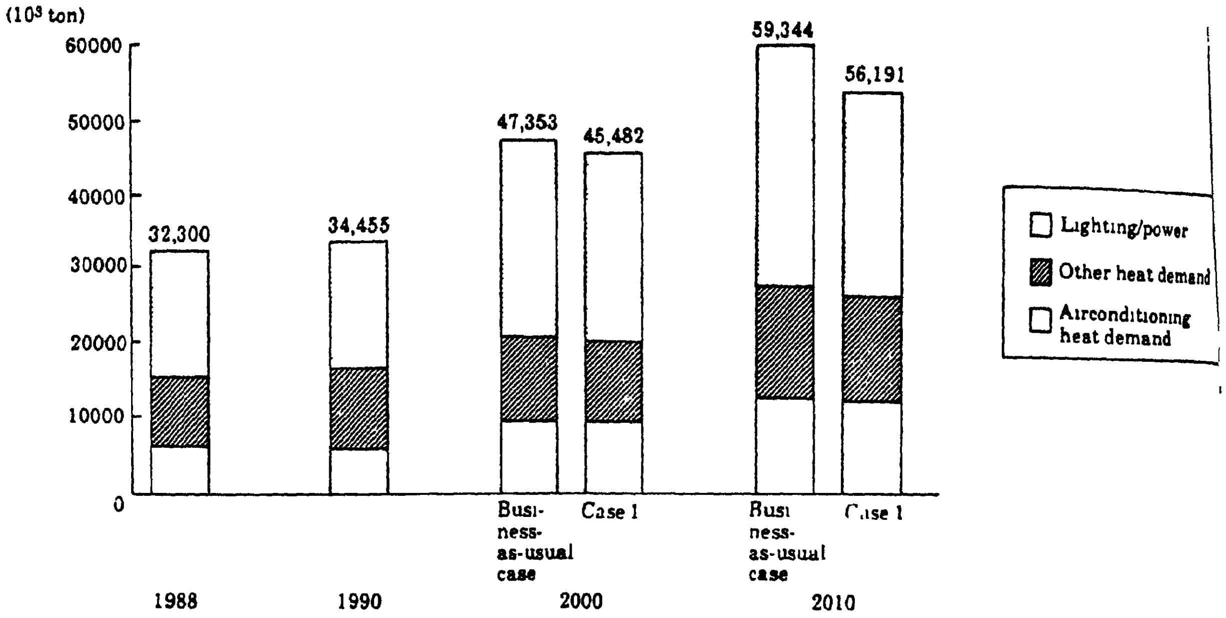


Table 11 : CO_2 Reduction Cost (Commercial Sector)

	Areas covered by conservation-oriented technologies (1,000 m²)	Incremental cost incurring in energy conservation (¥ 10⁹)
2000	120,088	2,251 4
2010	235,217	4,359 9

Table 12 : Reduced Energy Cost by Energy Conservation (Commercial Sector)

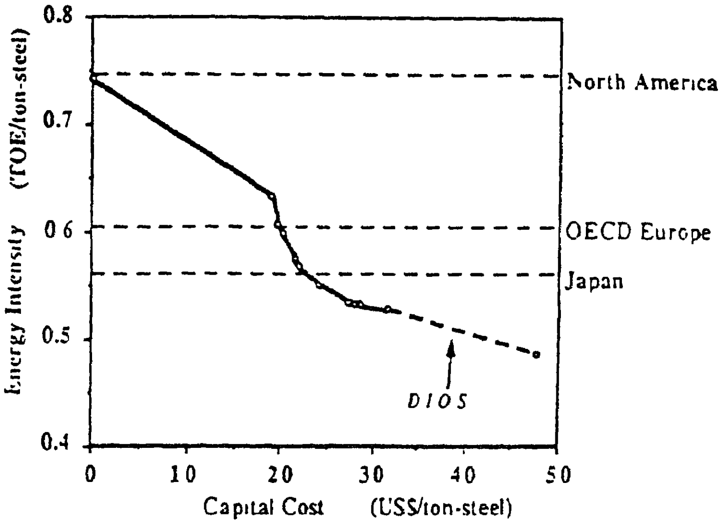
	Total energy use in 1988-2010 (10⁶ Mcal)	Energy conservation in volume (10⁶ Mcal)	Energy conservation in value (¥ 1 mil)
Business-as-usual case	10,826,598		
Energy conservation case	10,453,586	373,012	6,858,120

Industrial sector in Japan

Here we show the bottom-up method to evaluate effectiveness of energy conservation measures in industrial sector used in the paper by Y. Kaya et al.[4] The cost and total energy conservation measures in energy intensive industries such as iron/steel (Figure 8, 9; where D.I.O.S. is an abbreviation for "Direct Iron Ore Smelting reduction process), cement production (Figure 10, 11) and paper/pulp industries (Figure 12, 13) are shown.

In the evaluation of the iron/steel industry, we can see that the energy conservation cost in Japan is quite higher than that of OECD Europe and North America. This is because Japan has already attained energy saving technologies i.e., there is not much energy conservation potential left in comparison to other developed countries. Tables of technology-wise cost estimation are listed in Appendix D, where we assume that the life time of each measure to be 10 years.

Figure 8 : Relation Between Energy Intensity and Cost in Iron/ Steel Industry



Regions

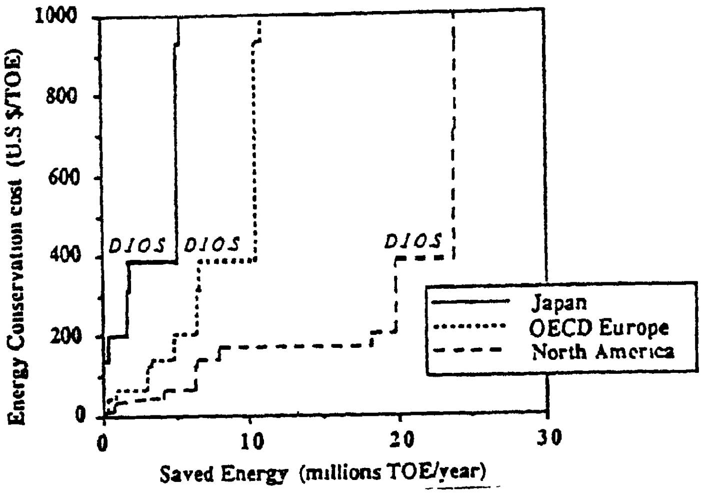


Figure 10 : Energy Intensity vs Cost in Cement Industry

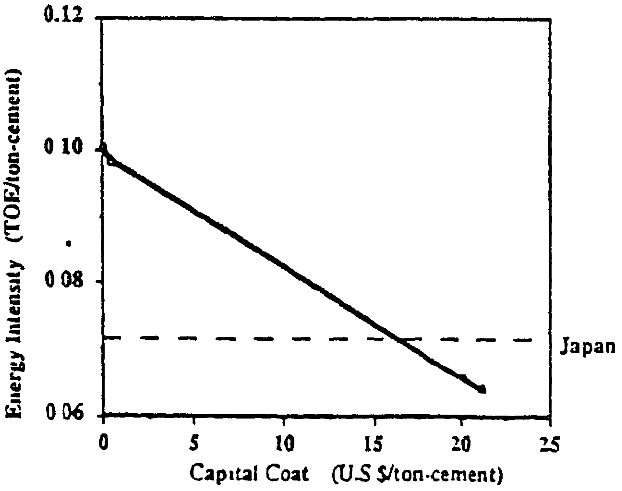


Figure 11 : Energy Conservation in Cement Production

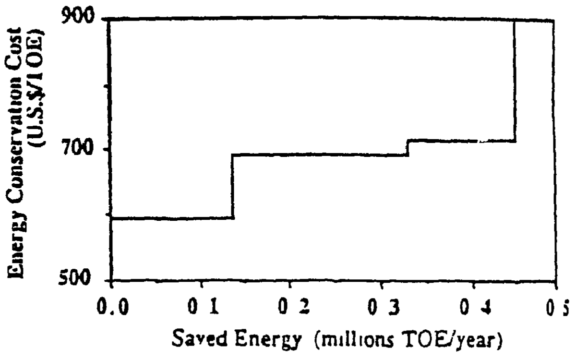


Figure 12 : Energy Intensity vs Cost in Paper/Pulp

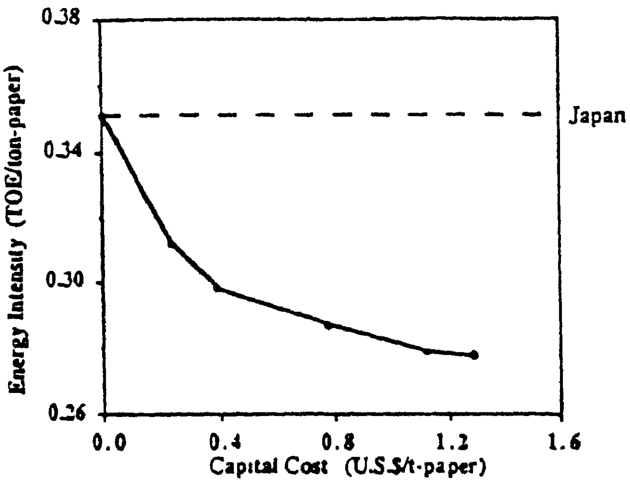
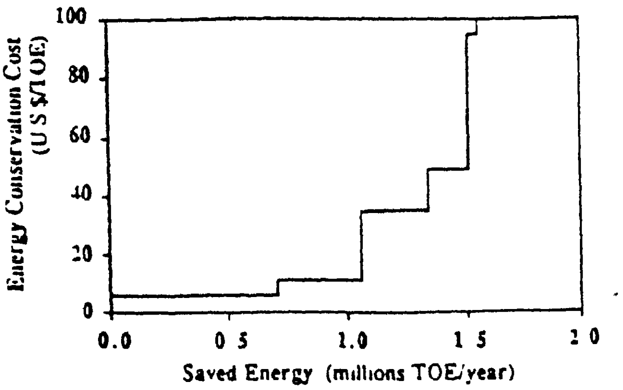


Figure 13 : Energy Conservation in Paper/Pulp Industry



Energy conversion sector in Japan

Kaya et al. also evaluate the energy conservation cost of coal fired power plant and natural gas fired power plant in comparison to OECD Europe and North America. The same tendency can be seen from Figure 14 and 15.

Figure 14 : Energy Conservation (Coal Fired Power Plants)

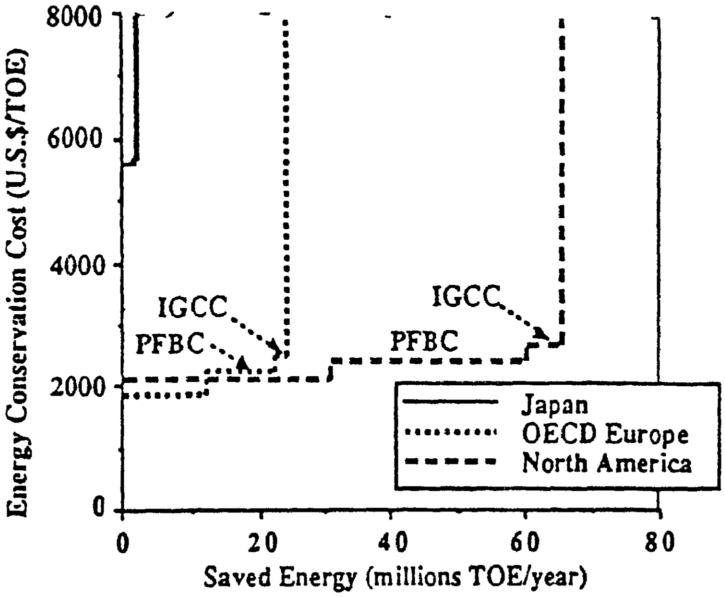
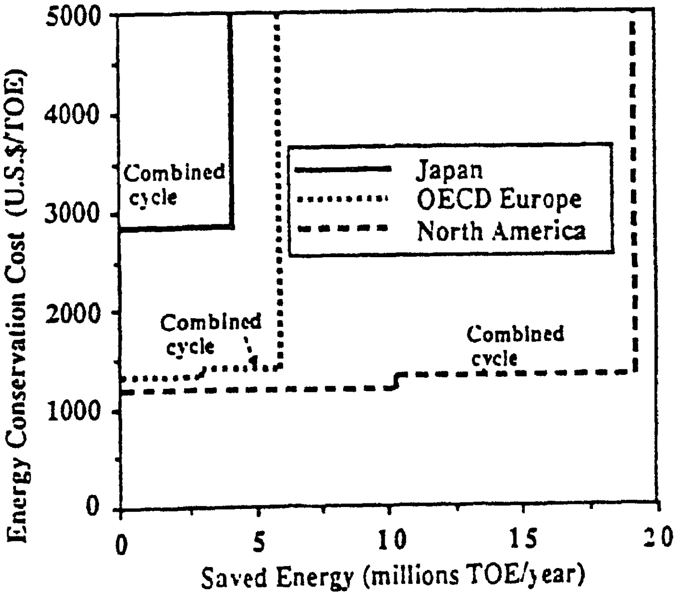


Figure 15 : Energy Conservation (Natural Gas Fired Power Plants)



Roles of technologies and Japan's international cooperation

Reduction Potential in other countries

Needless to say, technologies can play overwhelming roles in stabilizing or reducing CO_2 emissions. In the long or ultra-long run, to reduce GHG concentrations in the atmosphere critically requires a wide range of innovative technologies to be put to practical use.

Even from the short/medium-term viewpoints, the development and introduction of new technologies doubtlessly is a matter of extreme importance. But, to transfer the already established technologies and promote their use is very important as well. For instance, if countries all over the world use energy as efficiently as Japan, ranking among the world top class, CO_2 emissions could considerably be cut.

As shown in Table 13, Japan's Economic Planning Agency estimates that identical specific consumption of energy to Japan's, if achieved by the rest of industrialized countries, could lead to a 54.4% cut in CO_2 emissions from manufacturing industries, a 8.6% cut from the power industry, and a 13.0% cut from passenger cars, and that the effect on total CO_2 reductions could reach a high 21.5%. Likewise, as presented in Table 14, comparable specific consumption to energy of Japan's if acquired by the Soviet Union/Eastern Europe and major LDCs, could result in a 69.5% cut in CO_2 emissions from manufacturing (the three major industrial sources of steel, chemicals and cement), and a 37.3% cut from power generation. When combined, the effect of total CO_2 reductions could reach 50.9% in these two sectors, the agency says[5].

Also, similar estimates made by the Japan Development Bank show that CO_2 emissions from steelmaking worldwide could be slashed a total of 32% only if steelmakers throughout the world improved efficiency of their energy use to the same level as achieved by their Japanese counterparts, and that CO_2 emissions from power generation worldwide could be cut a total of 26% if generators all over the world improved their heat efficiency to the same level as practiced by their Japanese counterparts.

Of course, such an assumption itself should result in a rough argument, because it neglects differences in actual conditions resulting from peculiarities of individual countries or regions. Nevertheless, these estimates suggest that the already established technologies, if adequately transferred and widely in use, could have great potential effects on CO_2 reductions. Also suggested is that Japan, capable of making great international contribution from this aspect, is required to make active commitments to this field.

Table 13. Potential of CO_2 Reductions When Advanced Countries Energy Efficiency to be Improved to Japanese Level

(Mt-C)

		Manufacturing Industry								Power Industry				Passenger Cars	TOTAL
		Total	Iron/ Steel	Chemical	Non-Steel	Cement	Foods	Paper/ Pulp	Others	Total	Coal	Oil	Gas		
U.S.	Present	202.17	28.81	61.68	7.63	19.50	18.46	35.60	30.50	448.15	382.84	29.69	35.62	324.84	975.16
	Improved	73.39	15.79	29.02	1.26	5.08	3.55	2.36	16.33	410.60	354.08	26.56	29.96	280.74	764.73
Canada	Present	22.22	4.65	8.07	0.79	1.07	1.09	2.74	3.82	24.07	21.69	1.92	0.46	27.62	73.91
	Improved	6.95	2.01	2.46	0.19	0.50	0.33	0.22	1.25	21.96	20.03	1.72	0.20	23.88	52.79
France	Present	26.05	6.16	10.40	0.82	3.10	1.77	0.80	3.00	3.57	3.05	0.51	0.0	28.44	58.06
	Improved	17.25	5.77	6.17	0.35	1.19	0.70	0.28	2.81	3.07	2.69	0.38	0.0	25.02	45.34
Germany (West)	Present	40.78	12.46	14.96	0.84	4.07	2.16	1.46	4.85	46.29	42.26	1.36	2.67	34.93	122.00
	Improved	28.31	8.10	12.19	0.41	1.65	0.88	0.30	4.79	41.35	38.22	1.06	2.06	30.72	100.38
Italy	Present	22.09	5.29	7.42	0.13	4.51	0.96	0.70	3.08	24.74	6.58	14.92	3.24	23.95	70.78
	Improved	14.13	5.29	4.81	0.13	1.11	0.35	0.14	1.86	23.25	6.58	13.74	2.90	21.07	58.45
U.K.	Present	25.63	5.16	8.60	0.54	2.39	1.83	0.91	6.20	50.73	46.25	4.28	0.21	28.53	104.89
	Improved	14.27	3.86	5.87	0.20	1.15	0.62	0.28	2.30	47.17	43.16	3.79	0.21	25.09	86.55
Other OECDS	Present	71.40	17.51	24.35	3.71	9.40	5.09	3.46	7.90	64.89	54.30	3.16	7.45	116.10	252.39
	Improved	32.80	11.48	10.94	0.56	2.71	1.86	0.64	4.62	58.01	48.51	3.12	6.39	102.10	192.91
Total	Present	410.34	80.04	135.48	14.46	44.04	31.36	45.67	59.35	662.44	556.97	55.84	49.65	584.41	1657.19
	Improved	187.10	52.30	71.46	3.10	13.39	8.29	4.22	33.96	605.41	513.27	50.37	41.72	508.62	1301.13

Note : 1. Calculated from "OECD, Energy Balances of OECD Countries", "United Nation, Industrial Statistics Year Book" and others.
2. CO_2 emissions in 1986 for manufacturing industry, 1988 for power industry and passenger cars.

Sources: Economic Planning Agency of Japan, July 1991.

Table 14. Potential of CO_2 Reduction When USSR/Eastern Europe and Major LDCs Energy Efficiency to be Improved to Japanese Level

(Mt-C)

		Manufacturing Industry				Power Industry				TOTAL
		Total	Iron/ Steel	Chemical	Cement	Total	Coal	Oil	Gas	
USSR	Present	202.43	105.88	60.28	36.27	303.10	124.15	66.03	112.92	505.53
	Improved	57.73	38.46	11.40	7.87	181.95	86.31	37.18	58.46	239.68
Poland	Present	12.29	6.71	1.86	3.72	49 58	47.10	1.64	0.83	61.87
	Improved	6.16	3.77	1.22	1.17	27.79	26.79	0.73	0.35	33.95
Yugoslavia	Present	4.31	1.65	1.40	1.27	14.47	12.56	1.60	0.31	18.78
	Improved	2.64	0.78	1 31	0 55	11.12	10.18	0.72	0.22	13.76
Other E Europe	Present	47.99	24.86	10 30	12.83	91 74	79 77	6.27	5.70	139.73
	Improved	19.02	9.05	6 78	3 20	41.75	37 28	2.51	1.97	60.77
Sub-Total	Present	267 02	139.10	73 84	54 09	458.89	263 58	75 54	119.76	725 91
	Improved	85.55	52.06	20.71	12 79	262 61	160.48	41.14	61.00	348.16
China	Present	150.54	62.70	49.76	38 08	114 29	102.53	11.57	0.19	264.83
	Improved	32.20	15.03	4 01	13.16	90.80	80.86	9 80	0.14	123.0
India	Present	22.66	9.74	8.99	3.93	45.80	42.20	2.09	1.51	68.46
	Improved	6.94	3.35	0 80	2.78	32.51	31.04	1.18	0 29	39.45
Brazil	Present	14.42	6.36	6.71	1.35	2.30	0.96	1.34	0.0	16.72
	Improved	11.15	4.99	4.81	1.35	1.64	0 65	0.99	0.0	12.79
Korea	Present	11.89	4.09	3.98	3.82	8 22	4.72	2 10	1 40	20 11
	Improved	7.22	2.09	3.57	1.55	7.35	4.27	1 92	1.16	14 57
Sub-total	Present	199.51	82.89	69.44	47.18	170.61	150.41	17.10	13.10	370.12
	Improved	57 51	25.46	13.19	18.84	132 30	116.82	13 89	1.59	189.81
Total	Present	466.53	221.99	113 28	101.27	629 50	413 99	92 64	122 86	1,096.03
	Improved	143.06	77.52	33.90	31 63	394.91	277.30	55.03	62 59	537.97

Note : See Table 2
Source : Ibid

Capital Cost Needed

In the last subsection, we conclude that

(1) In the developing countries, about 20% of CO_2 emissions can be reduced in case that the saving level of manufacturing, electricity and automobile can be at the level of Japan.

(2) In Eastern Europe and major developing countries (China, India, Brazil and South Korea), around half of the CO_2 emissions can be reduced in case that the high carbon intensity industries --- steel/chemical/cement/power generation --- can be at the same level of Japan.

Next, the capital cost of above mentioned potential in Eastern Europe and developing countries is estimated. Two approaches are applied --- micro-economic[case 1] and macro-economic method[case 2] --- and show that 50-150 trillion yen is needed in case that the equipments are installed by 1989 and 100-300 trillion yen is needed in case installed by 2010 as shown in Table 15 and 16. These difference comes from the calculational method which treats the capital as net or gross (see Appendix E for details). It must be noted that the cost will be greater if the latest or future equipments are installed. However, it might be realistic to assume the on-going technologies to be installed to such countries.

Thinking over cost/benefit aspects, the above capital cost is equivalent to 10-30 thousand yen per tonne of carbon. On the other hand, reforestation in the tropical region is estimated by Grainger, to be equivalent to 9 thousand yen per tonne of carbon.

Table 15 : Cost Estimation by Micro-Economical Method

unit trillion yen(1988)

	Installed in 1989						Installed by 2010					
	manufacturing				power	TOTAL	manufacturing				power	TOTAL
	total	steel	chemical	ceramics			total	steel	chemical	ceramics		
Soviet Union	14 64	9 04	2 37	3 23	9 36	24 00	23 37	14 40	3.78	5 15	14 95	38 33
Poland	1 52	0 88	0 26	0 38	1 07	2 59	2 42	1 40	0.42	0 60	1 71	4 13
Yugoslavia	0 67	0 18	0 28	0 22	0 44	1.11	1 08	0 29	0 44	0 35	0 70	1 77
Other E E	4 96	2 29	1 58	1 09	1 68	6 64	7 92	3 65	2.53	1.74	2 67	10 60
total	21 79	12 39	4 49	4 91	12 55	34 34	34 80	19 78	7 17	7 85	20 03	54 83
China	7 73	3 12	0 64	3 96	3 54	11 27	18 37	7 43	1 52	9 42	8 42	26 79
India	1 67	0 69	0 14	0 84	1 25	2 92	3 97	1 65	0.34	1 99	2 98	6 95
Brazil	2 54	1 06	0 88	0 60	0 07	2 62	6 05	2 52	2 09	1 43	0 17	6 22
South Korea	1 63	0 44	0 63	0 56	0 34	1 97	3 88	1 04	1 51	1 34	0 81	4 69
total	13 57	5 32	2 30	5 96	5 21	18 78	32 27	12 64	5 46	14 18	12 38	44 65
TOTAL	35 37	17 70	6 79	17.76	17 76	53 12	67 07	32 32	12 63	22 03	32 41	99 48
cf Japan	11 40	5.73	3 97	1.70	3 25	14 65						

Table 16 : Cost Estimation by Macro-Economical Method .

unit trillion yen(1985)

	Installed by 1989						Installed by 1989					
	manufacturing				power	TOTAL	manufacturing				power	TOTAL
	total	steel	chemical	ceramics			total	steel	chemical	ceramics		
Soviet Union	45 86	25 40	9 08	11 38	20 29	66 15	73 23	40 56	14 50	18 17	32 39	105 62
Poland	4 81	2 46	1 02	1 33	2 32	7 13	7 68	3 93	1 62	2 13	3 70	11 38
Yugoslavia	2 33	0 51	1 06	0 77	0 94	3 28	3 72	0 81	1 69	1 23	1 51	5 23
Other E E.	16 35	6 42	6 08	3 85	3 63	19 98	26 11	10 26	9 70	6 15	5 79	31 90
total	69 35	34 79	17 23	17 33	27.18	96 53	110 73	55 55	27 51	27 67	43 40	154 13
China	25 21	8 77	2 45	13 98	27 18	32 88	59 92	20 86	5 82	33 24	18 25	78 17
India	5 44	1 94	0 55	2 95	2 71	8 15	12 93	4 62	1.30	7 00	6.45	19 38
Brazil	8 48	2 98	3 38	2 13	0 16	8 64	20 16	7 08	8 03	5 05	0 38	20 54
South Korea	5 64	1 23	2 43	1 98	0 74	6 38	13 41	2 93	5 78	4 71	1 75	15 16
total	44 77	14 93	8 81	21 04	11 28	56 05	106 42	32 49	20 93	50 01	26 82	133 24
TOTAL	114 12	49 72	26 04	38 37	38 46	152 58	217 15	91 04	48 44	77 68	70 23	287 38
cf Japan	37 34	16 09	15 24	6 00	7 04	44 37						

Conclusion and discussions

In this paper, we showed the past trend of energy demand and CO_2 emissions in Japan. It can be seen that after 1973, total energy demand and CO_2 emissions have not increased very much in comparison to the growth of GNP. This tendency owes much to the technological progress of energy conservation. However, it must be noted that the recent trend shows the rapid growing of energy demand and CO_2 emissions contrary to the government's policy.

Next, simulation exercises were carried out which aimed at stabilizing CO_2 emissions at the 1989 level by 2000/2010 and at the 2000 level in and after 2000 (in the standard case). It was found that the latter requires the least reduction in GNP growth rate and therefore seems most feasible and realistic.

In Japan, the energy consumption has played the most important role to reduce energy consumption and CO_2 emissions. A lot of technologies have been established and are now undertaken. However, potential and total cost are not clear. So, some cost-estimating examples are presented concerning some energy saving technologies. Due to its high level of energy conservation, the CO_2 abatement cost in Japan is much larger than in any other country. So, it might be optimal to transfer some of the cost and technologies to other, especially, developing countries. A rough example of CO_2 reduction potential and cost estimation was also shown.

Appendix A.

Energy-Environment Policy of Japanese Government and its Key Issues

A.1 Tough energy targets

The Ministry of International Trade and Industry (MITI) published in June 1990 its latest long-term energy supply-demand outlook. It calls for a harmony among "generosity of affluence", "preservation of global environment" and "energy security", and puts forth policy targets to (1) help the economy grow an average 4% annually in 1988-2000, and 3% in 2000-2010, (2) make carbon-rich coal and oil use flat from 2000 and on, (3) increase nuclear, LNG and new energy supplies as much as possible, and (4) make utmost efforts for energy conservation.

However, these energy targets are so tough that it can be said that extreme difficulties should be overcome to achieve them. How come? When the economy is kept growing 4% and 3% annually, even if successful efforts were made for not only recording as high energy conservation rates (energy/GNP unit) as 23%/12 years (2.1%/year) and 36%/22 years (1.9%/year for 2000-2010) each, which are identical to those registered during the past two oil crises, but lowering CO_2 emissions per GNP unit by 28% in 2000 and by a hefty 45% in 2010, total CO_2 emissions would result (2.7%/year) in a net increase of 16% in 2000 ($[1 + (0.04 - 0.027)]^{12} = 1.16$), and a 17% rise in 2010 over the 1988 level.

Japan is one of the countries having achieved the most remarkable fuel switching results in the world since the first oil crisis, and also among the countries showing least CO_2 emissions per GDP unit. In other words, making further progress in these fields is nothing but hard in both technical and cost terms.

A.2 Gaps between the goal and reality

Since energy, economic growth and environment tend to fall in trade-off relations each other, it is a task of extreme difficulty to secure a harmony among the three particularly when the economy keeps expanding. Indeed, with the record-breaking booming Japanese economy since 1987 still continuing, Japan's energy consumption also keeps growing much larger than predicted, making it harder to attain the CO_2 stabilization targets.

Originally, it is thought that the CO_2 stabilization targets in the action program would manage to be attained only if per capita emissions, instead of total emissions, were taken as the norm because, given the MITI's latest long-term outlook, it is obviously impossible to trim total CO_2 emissions, in addition to delaying the start of reducing efforts two years to 1990, and with the remaining assumptions in the outlook proving correct.

In reality, however, over the two years of 1989 and 1990, GNP grew an average 5.3% per annum, and energy consumption increased an average 4.5% annually, pushing CO_2 emissions up 7.2% in two years. Taking the incremental energy consumption in the starting two years for granted, if the incremental portion should be covered with coal and the rest of the conditions in 1991-2000 would develop as assumed in the outlook, CO_2 emissions in 2000 and 2010 should be 30% and 33% larger than in 1988, respectively, thus totally jeopardizing a possibility of attaining the targets stated in the action program.

On the contrary, to curb energy consumption in 2000 at the exact level assumed in the long-term outlook, energy consumption in 1991-2000 is allowed to grow but as little as an average 1.3% annually. Given that energy consumption in 1991 is growing an estimated around 3.5%, actually remaining room for an additional growth should become even more marginal (a little less than 1%), which can never be realistic at all. Any industrialized countries other than Japan, more or less, have shown similar situations over the past few years.

A.3 A scenario in which a balance is taken with the economic growth

The MITI, in its latest long-term outlook, puts unusual remarks saying that Japan could be urged to make drastic reviews (downward revisions) of her economic growth and energy policies if she should come to face extremely difficult situations in international context in such agenda as CO_2 stabilization in the short run.

Then, assuming that Japan's economic growth would be lower than assumed in the long-term outlook, what conditions would be needed to stabilize total CO_2 emissions virtually at the 1990 level? If GNP is taken simply as a function of labour productivity, in a scenario assuming that Japan's working hours would decrease from 2,088 hours/year per worker in 1989 to 1,800 hours in 2010, and that the labour productivity would rise from recent trends to 3.0%/year/worker, the GNP growth could fall to 2.9%/year/worker in 1989-2000, and to 2.2%/year/worker in 2000-2010, even by taking an expected increase in working population for granted. Then, applying the same energy conservation rates (1.6%/year in 1989-2000 and 1.1%/year in 2000-2010) as obtained from elasticity of energy consumption to GNP unit (0.45 and 0.37, each, in corresponding periods) in the long-term outlook, the growth of energy consumption would be 1.3%/year and 0.8%/year, respectively.

In addition, assuming that coal would be the loser in lower energy consumption than predicted in the outlook and responsible for the entire portion of lost energy use, total CO_2 emissions would result in a 2% rise in 2000 and a 3% fall in 2010 (the same value). On a per capita basis, CO_2 emissions could virtually be stabilized at the 1990 level as originally planned. Consequently Japan's coal use would total 111 million tonnes in 2000 and 82 million tonnes in 2010 (compared with 142 million tonnes, each, projected in the MITI outlook), thus causing curtailment of coal-fired thermal power plants and surging steel imports. This could bring about drastic changes in the future shape and management of the Japanese economy, and thereby the Japanese ability can inevitably be damaged to some extent to fulfill international requests for adjustment of Japan-U.S. structural impediments and growing ODA, among others. Thus, this is not an easy scenario by all means.

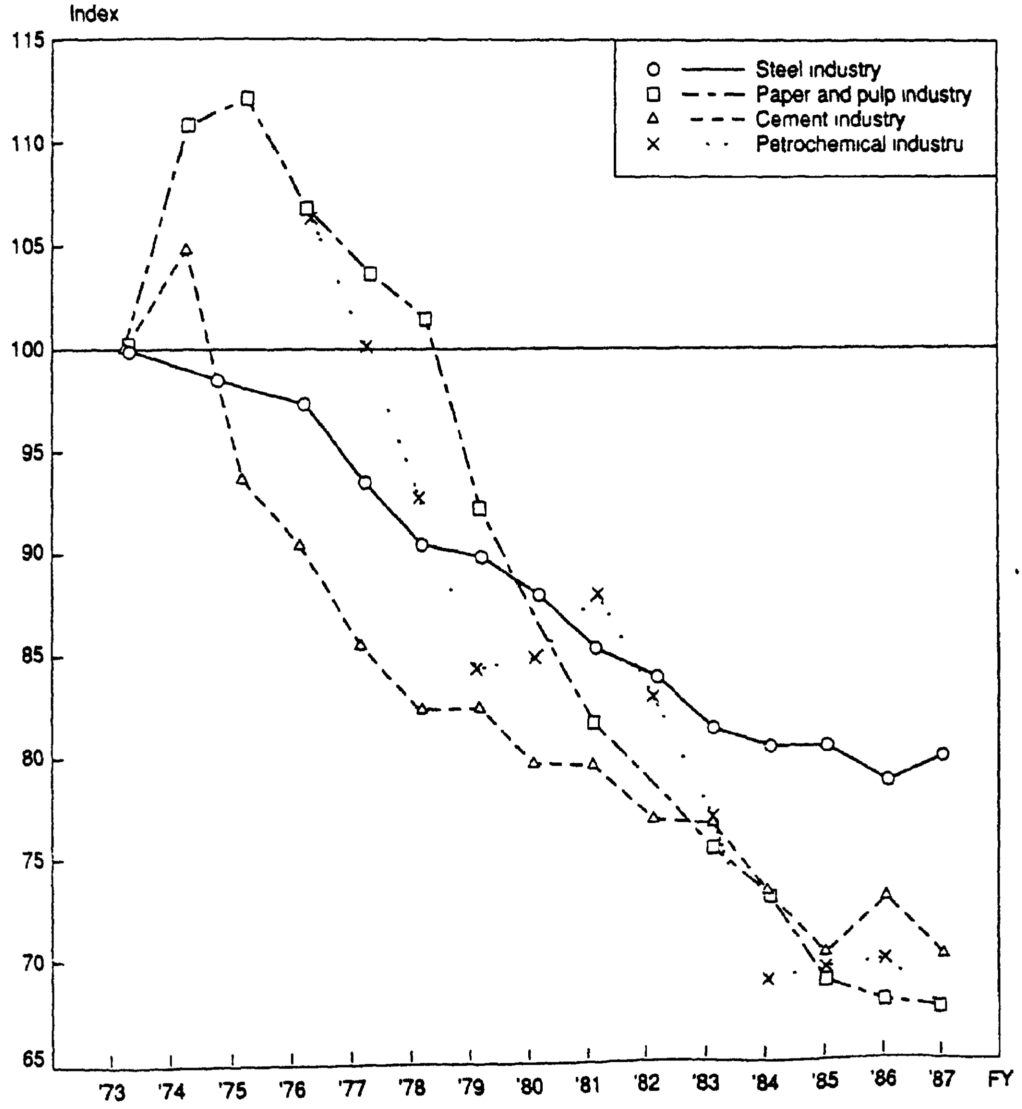
Appendix B.

Overview of New/Renewable Energy Technologies

- Renewable energies
  - Solar energy
    - Solar photovoltaic power generation
    - Solar thermal electric generation
    - Active solar systems
    - Passive solar systems
    - Solar chemistry
  - Geothermal energy
    - Geothermal prospecting technologies
    - Drilling and extraction technologies
    - Steam power generation
    - Flash power generation
    - Total flow power generation
    - Binary cycle power generation
    - Hot dry rock power generation
    - Magma power generation
  - Wind energy
    - Survey on wind conditions
    - Wind power generation systems
  - Hydrogen energy
    - Production technologies
    - Transportation and storage technologies
    - Utilization technologies
    - Safety maintenance technologies
  - Bioenergy
    - Biomass utilization technologies
    - Energy conversion technologies utilizing biofunctions
  - Ocean energy
    - Ocean thermal energy conversion
    - Wave power generation
    - Tidal and ocean current power generation
- Fuel conversion
  - Coal liquefaction
    - Direct liquefaction method
    - Indirect liquefaction method
    - Hydropyrolysis
    - Co-processing
  - Coal gasification
    - High calorific gasification technologies
    - Medium calorific gasification technologies
    - Low calorific gasification technologies
  - Liquefaction and decarbonization of natural gas
- New energy utilization systems
  - Combined systems
    - Long-distance clean energy transportation
    - Integrated energy systems
  - Common fundamental technologies
    - Effective utilization technologies for variable natural energy
    - Effective utilization technologies for low temperature natural thermal energy

Appendix C.

Past Trend of Energy Conservation in Major Industries in Japan



Note) 1 As for the petrochemical industry 1977 is shown as 100

2 Steel industry figures show real basic unit adjusted to fiscal 1973 production conditions, all others show nominal basic unit.

Source) MITI

Technological Prospects on Energy conservation in Japan

Theme	Category	Contents	Target year(outlook)
Coal	Electricity	gasification/combined	2000
	Coal	gasification	2000
		fluidized bed combustion	2000
		liquification	2010
		hydrogen production	2000
		high density slurry	1995
		deash/desulfur slurry	2010
		SNG process	2000
Oil	Oil	hydrogen production	2010
		improvement of combustion technology	2000
Nuclear	Electricity	super-safety small reactor	2000
		plutonium light-water reactor	1995
		recycled gas by high-pressure reactor	2020
		fast breeder reactor	2020
		nuclear industrial complex	2015
		high-temperature gas reactor	2010
		uran enrichment by laser	2010
		retreatment	1998
Fuelcell	Electricity	phosphoric acid type	1995
		melting carbonic acid type	2020
		solid electrolyte type	2020
	Gas	phosphoric acid type	1993
		solid electrolyte type	2000
		limited space co-generation	1995
	Oil	petroleum-based type	2000
Super-conduction	Electricity	generator	2010
		storage system	2020
		cable	2010
		transformation	2020-
Power	Electricity	photovoltaic	1995
		variable speed pumping-up	1993
		sea-water pumping-up	2000
New material	Electricity	high-temperature ceramic gas turbine	2000
Bio-technology	Electricity	hydrogen production	2030
		desulfurization of coal	2020
		production of oil	2005
Non-oil engine	Electricity	engine using gas/alcohol	1995
Steel	Steel	melting scrap	1990
		thin slab continuous casting	1995
		thin board continuous casting	2000
		direct reduction	2000
		semi-solidification processing	2000
		direct-use of coal	2010
Battery	Electricity	new type of batteries	2000
		electric car	2010
AI	Electricity	application to energy system	2000

Appendix D.

Tables of Technology-wise CO_2 Abatement Cost Estimation in Industrial Sector

Energy Conservation Technologies in Iron & Steel Industry

Energy conservation technologies	Energy Intensity (TOE/ton-steel)	Investment ($/ton-steel)
base case	0.742	0 0
Basic oxygen furnace	0 633	18 8
Hot direct rolling process	0 608	19 6
Blast furnace top pressure recovery turbine (wet type)	0 597	20.1
Converter waste gas-collecting unit	0 575	21 5
Sealed-type converter waste gas-collecting unit	0 570	21 6
Cokes furnace humidity-controlling unit	0 568	21 9
Continuous casting unit	0 551	24 1
Cokes dry quenching unit	0 535	27 5
Blast furnace top pressure recovery turbine (dry-type)	0 533	28 0
Slag sensible heat-recovering unit	0 532	28 7
Continuous annealing line	0 529	31 6
Direct Iron Ore Smelting Reduction Process	0.487	47 7

* The upper the measure, the lower the cost of saving energy, except for Basic oxygen furnace and Direct iron ore smelting reduction process.

Energy Conservation Technologies in Cement Production

Energy conservation technologies	Energy Intensity (TOE/ton-cement)	Investment ($/ton-cement)
base case	0 1004	0 0
Power generator utilizing waste heat	0 0982	0 5
New suspension pre-heater kiln	0 0682	18 4
Roller-type vertical crusher (finishing process)	0 0658	20 1
Roller-type vertical crusher (raw material process)	0 0642	21 2

Energy Conservation Technologies in Paper & Pulp Industries

Energy conservation technologies	Energy Intensity (TOE/ton-paper)	Investment ($/ton-paper)
base case	0.351	0.00
High-performance surface press dewatering unit	0.312	0.23
High-performance sizing press	0.298	0.39
Pre-immerging continuous digesting	0.287	0.78
Substitution breaching unit	0.279	1.13
High-performance pulp cleaning unit	0.278	1.29

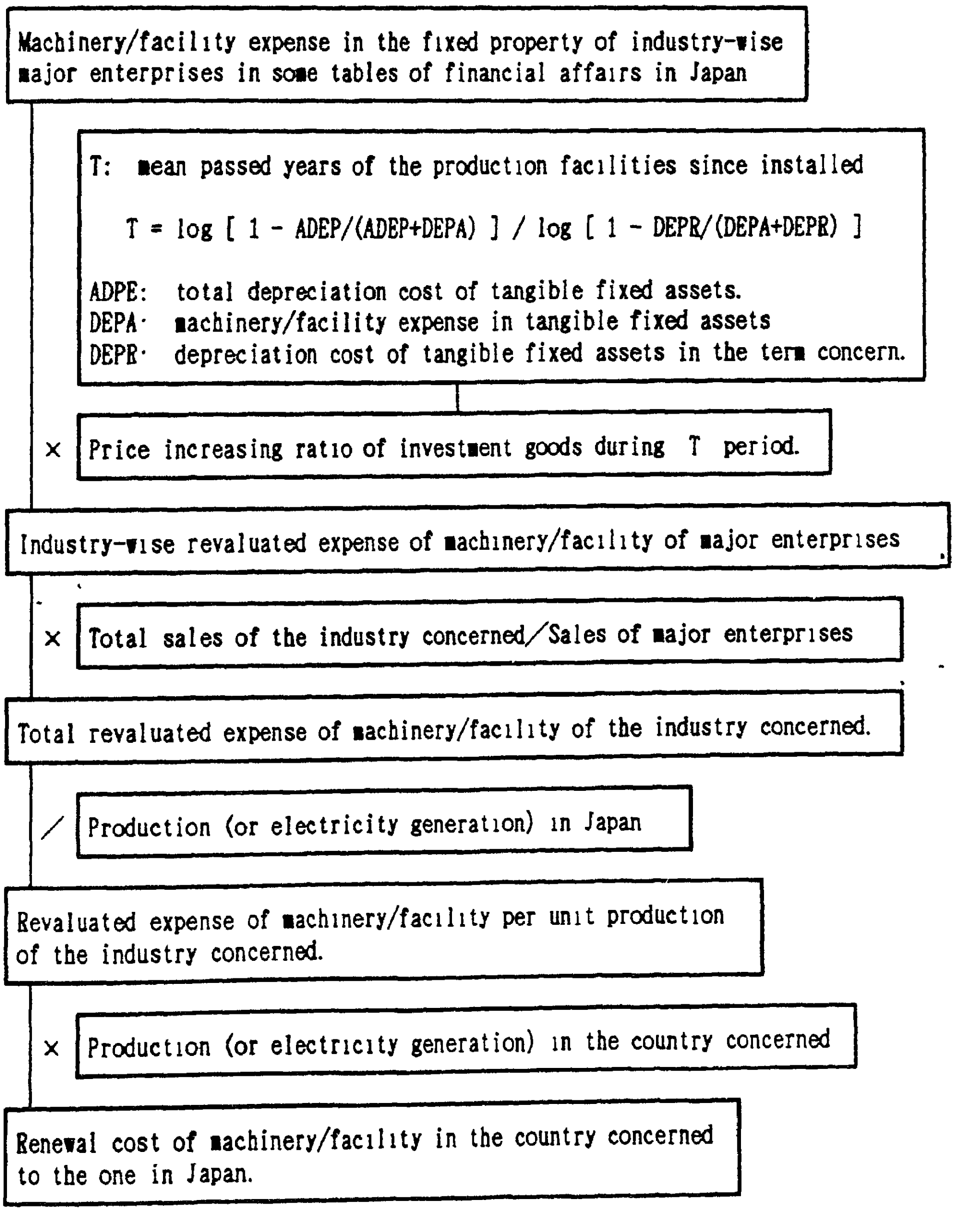
The Efficiencies of Energy Conversion Technologies (HHV)

Conventional Coal-fired Power Plant	North America	35.1%
	OECD Europe	34.7%
	Japan	38.0%
Pressurized Fluidized Bed Combustion		41.0%
Integrated coal Gasification Combined Cycle		41.6%
Conventional Gas-fired Power Plant	North America	33.7%
	OECD Europe	34.4%
	Japan	40.3%
Combined Cycle		47.0%

Appendix E.

Renewal Capital Cost Estimation Flow chart

[Case 1]



Machinery/facility expense in the fixed property of industry-wise major enterprises in some tables of financial affairs in Japan

T: mean passed years of the production facilities since installed

$$T = \log [1 - ADEP/(ADEP+DEPA)] / \log [1 - DEPR/(DEPA+DEPR)]$$

ADPE: total depreciation cost of tangible fixed assets.
DEPA: machinery/facility expense in tangible fixed assets
DEPR: depreciation cost of tangible fixed assets in the term concern.

× Price increasing ratio of investment goods during T period.

Industry-wise revaluated expense of machinery/facility of major enterprises

× Total sales of the industry concerned/Sales of major enterprises

Total revaluated expense of machinery/facility of the industry concerned.

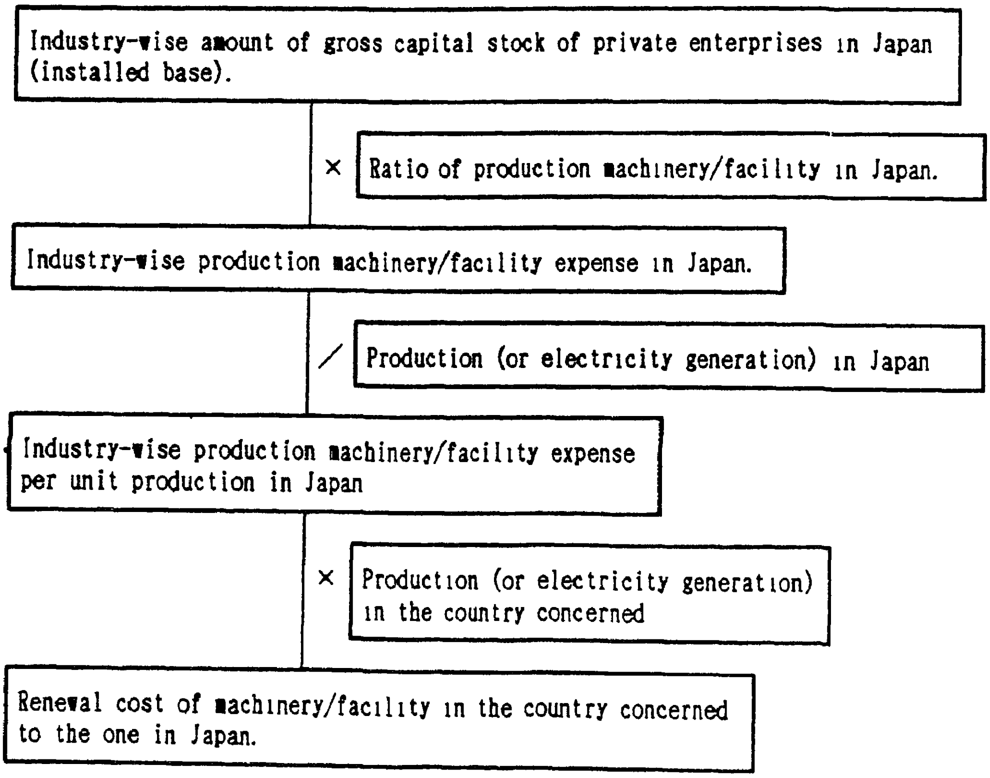
/ Production (or electricity generation) in Japan

Revaluated expense of machinery/facility per unit production of the industry concerned.

× Production (or electricity generation) in the country concerned

Renewal cost of machinery/facility in the country concerned to the one in Japan.

[Case 2]


Industry-wise amount of gross capital stock of private enterprises in Japan (installed base).
×
Ratio of production machinery/facility in Japan.
Industry-wise production machinery/facility expense in Japan.
/
Production (or electricity generation) in Japan
Industry-wise production machinery/facility expense per unit production in Japan
×
Production (or electricity generation) in the country concerned
Renewal cost of machinery/facility in the country concerned to the one in Japan.

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CHAPTER 8 : SOUTH KOREA COUNTRY PAPER

Joo-Heon Park
Korea Energy Economics Institute
South Korea

EXECUTIVE SUMMARY

This paper presents overview of Korean energy system considering the relations with environmental conservation. The major sources causing emission problems are discussed and some measures taken to reduce the air pollution in Korea are introduced.

The Korean government has been trying to improve the environment and to control the gas emissions fo environmental conservation. The environmental policy in Korea has been focused on balancing economic growth and environmental conservation.

For the purpose of reducing gas emissions, the fuel quality should not be only improved but the improvement of energy efficiency should also be reinforced.

Introduction

Korea has achieved a remarkable economic growth over the last two decades. Gross national product has maintained an average growth rate of 8.6% per annum in real terms during the same period and GNP per capita has also increased from $288 in 1971 to $6,569 in 1989 in nominal term. Resulting from the fast economic growth, total energy consumption has also increased sharply. Total primary energy consumption in 1980, 43,911 thousand TOE has more than doubled to be 93,193 thousand TOE in 1990. Korea is likely to keep its economy growing at 9% and higher in the short run, and its potential growth is projected at 6-7% in the long run through 2000.

Economic development, energy use and environmental issues have become more closely linked in recent years than before. Energy use is one of the major sources of environmental deterioration. As the economic development should accompany the intensive energy use, there is a conflict in some sense between economic development and environmental protection. It is highly probable that the vigorous economic growth and increasing energy consumption will be coupled with CO_2 emissions in huge quantities.

In the course of development, Korean economy has experienced a significant structural change in terms of energy use. In the 1970's, Korean economy had grown through expansion of energy intensive heavy and chemical industries. In the 1980's, however, the industrial development has depended more heavily on expansion of less energy intensive machinery and equipment industries including ship building, automobiles and electronic industries. Nevertheless, Korean economy still remains among the energy intensive countries. But without this structural change, the energy intensity would be much higher than now. The energy intensity per GDP in Korea is shown to be higher than those of other countries such as Japan, Taiwan or the US because the share of the energy intensive industries in the economy is still high.

The recent rise of environmentalism as a social issue in Korea, in the backdrop of rapid economic growth, was initiated by the public concern about the deterioration of environmental quality and increasing fear of health threat. Major sources of greenhouse gases (GHGs), in Korea consist of emissions from residential heating and cooking, industrial processes, electric power plants and automobiles. The amount of CO_2 emissions in Korea in 1990 is estimated to be approximately 64.7 million tonnes. It is estimated that CO_2 emissions in Korea will increase at about 5.5% per annum by the end of the century. However, the increasing rate of CO_2 emissions is expected to be stabilized at 2.0% after 2010.

The purpose of this paper is to introduce the Korean experience about the change in the energy consumption pattern, GHG emissions and measures taken to reduce GHG emission level. In order to estimate CO_2 emissions in the future, two comparable scenarios are taken, "High-Emission (HE)" scenario and "Low-Emission (LE)" scenario. These two scenarios are distinguished in terms of the opportunities of fuel substitution and of the possible improvement of energy efficiency. It should be noted that the other socio-economic variables affecting energy consumption are assumed to be fixed at the current level for both scenarios.

Energy demand and supply

Energy supply

Korea is poorly endowed with domestic energy resources. Its indigenous resources are limited only to anthracite, firewood and hydropower. Inevitably, in order to meet the increasing amount of energy needed for the continuous industrialization of the economy, Korea has had to import all other energy sources from abroad. Korea's import bills for energy amounted to $10.92 billion in 1990, of which $9.00 billion was paid for oil, and $1.27 billion for bituminous coal. Korea's import dependence ratio of energy consumption is very high, approaching 85.5% in 1989 (with nuclear energy included), and is likely to rise continuously in the future.

Energy demand

In the past, energy consumption in Korea has increased dramatically along with a very high GNP growth rate. The total primary energy consumption has doubled in every ten years and reached 92.8 million TOE in 1990. Per capita energy consumption in Korea has also increased from 1.18 TOE in 1981 to 2.17 TOE in 1990, which is, however, still far below the average of the developed countries. (Refer to Table 2).

The energy demand is expected to remain on the increasing phase for another couple of decades. The total final energy demand in Korea is projected to increase from 90.5 million TOE in 1990 to 204.9 million TOE in 2010. Such a high increase is mainly due to the expansion of industrial and transportation sectors, the shares of which in total energy consumption are expected to be 50% and 25% respectively while that of residential and commercial sector is expected to decrease to 11% in 2025. Per capita energy consumption in 2010 is also projected to be 3.4 TOE which is almost the same as the Japanese current level.

For the structure of primary energy demand by fuel type, it is projected that the shares of oil and gas will increase in the future at the cost of coal share. The shares of oil and natural gas are projected to increase to 55.9% and 6.6% respectively while that of coal is expected to decline to 21.2% in 2010. (Refer to Table 12)

Energy demand by sector

Glancing down Table 4, it is found that Korea's energy consumption pattern has changed since 1980 just after the second oil crisis.

The residential and commercial sector was larger than the industrial sector with its share of 45.3% in the total energy consumption compared with 38.5% of the industrial sector in 1975. The share of energy consumption in the industrial sector, however, outplaced the share of the residential and commercial sector due to the fast industrialization process. As a result, the major energy consumption sector in Korea shifted from the residential and commercial sector to the industrial sector in the late 1970's. The share of the industrial sector accounted for 48.2% while the residential and commercial sector recorded 29.2% in 1990. (Refer to Table 4)

Residential and Commercial Sector

Korea, being located in the continental climate zone, has four distinct seasons: moderate spring and fall, hot summer, cold winter,. Such a climatic condition is a key factor to affect energy consumption patterns in the residential and commercial sector at least in the short run. In fact, the energy demand in this sector is mainly due to space heating. The demand for anthracite in winter season is about three times as much as that in summer season. However, in the long run, the energy demand appears to be influenced by changes in various socio-economic variables such as economic growth rate, the number of household, the size of household, the urbanization rate, the ownership of appliances etc.

Although the sector has shown a slower growth rate of energy consumption than other sectors, energy consumption has increased at the rate of 2.4% and 7.5% per annum during the periods from 1986 to 1989 and in 1990 respectively. The structure of fuel mix in this sector has also changed significantly over the last decades shifting the major fuel from the solid fuels like firewood and anthracite to more convenient and clean fuels like oil and natural gas.

In the projection of the energy consumption, the paths, which some socio-economic variables follow, are assumed. The number of households is assumed to increase more rapidly than the population growth rate because there is a tendency towards small size households. Particularly, the number of households in urban area is projected to increase more rapidly than that in rural area as the urbanization rate is expected to increase from the current level of 66.0% to more than 83% in the 2000's. It is assumed that there is little difference in life-styles between urban and rural areas.

The energy demand by residential and commercial sector is mainly due to space heating. The share of space heating demand in total energy demand in the sector is more than 70% and is expected to be 60% in the future. However, heating energy demand per household is projected to decrease significantly by 38% of the current level in 2025 under the HE scenario because more efficient heating systems are expected to be introduced like district heating systems, improvement of insulation, fuel switching etc. In particular, district heating system is evaluated to be more favorable because of high urban concentration, high population density, and high rate of housing construction in Korea. District heating systems with combined heat and power plants will not only offer the opportunities to improve the efficiency of energy use but also make it possible to utilize cheaper and low quality fuels and would reduce space heating costs.

It is expected that fuel switching will happen actively in this decade from the solid fuels to liquid fuels. Anthracite has been the major fuel for space heating in this sector. Anthracite consumption had increased very rapidly by 6.2% per annum during the 1970's. However, in the middle of 1980's anthracite demand in this sector slowed down significantly. Furthermore, it began to decrease and this decreasing trend has continued since then. This recent decrease can be explained by the fact that the oil price has been stable in the 1980's and that people have begun to prefer clean energies like oil or natural gas to anthracite as their income rises. The share of anthracite is expected to decline to less than 5% in 2010. Oil and natural gas will be the major fuels in these sectors. Improvements of efficiency in energy use is also expected through this kind of fuel switching from less efficient to more efficient fuels.

Energy demand for cooking in the residential and commercial sector is relatively small, the share of which is estimated to be only 14% in 1985. Fuel switching began earlier in cooking demand than in heating demand. The average intensity will decline rapidly due to fuel switching from less efficient fuels to more efficient ones like LNG or LPG.

Diffusion of water heating is still low in Korea. 23% in urban and 12% in rural. The ownership of water heating devices is expected to reach 90% in urban area and 65% in rural area by 2025. The intensities of fuels will decrease about 40% of the current level by 2025 under the HE scenario due to improved efficiency of equipment and fuel substitution.

Electricity demand per household is expected to increase. Electricity demand in rural area will increase more rapidly in rural area than in urban area because the current consumption level in rural households is only about 60% of that in urban households.

Total residential energy demand is projected to increase moderately (from 20,507 thousand TOE in 1990 to 32, 901 thousand TOE in 2010). (Refer to Table 11). Among the reasons for such a moderate increasing rate are the expansion of district heating system, improvement of thermal insulation in new housing with more efficient heating devices, and fuel switching from less efficient fuels to more efficient fuels. Therefore the share of the residential sector in total final energy demand is expected to decline from 31.5% in 1985 to 12% in 2025.

Industrial Sector

The industrial sector consisting of mining, manufacturing and construction accounts for 42% of GDP and for 47% of total final energy consumption in Korea. Industrial energy consumption in Korea has increased from 10,760 thousand TOE in 1976 to 36,152 thousand TOE in 1990. Energy demand structure has also changed significantly within the industrial sector through restructuring the sector and substitution effort for oil. The substitution effort for oil in this sector was actively promoted after the second oil crisis, resulting that the share of oil demand has declined from 76.1% in 1976 to 51.6% in 1989, while that of bituminous coal has significantly increased from 9.7% in 1976 to 32.6% in 1989 (Refer to Table 6). Electricity consumption increased at a relatively high rate of 9.7% per annum during the period from 1977 to 1985 and 12.6% during the period from 1986 and 1989.

In the 1970's when the energy intensive industries such as steel and chemical industries, were intensively expanded, the increasing rate of industrial energy use was remarkably high, 13% per annum. But the sector has been restructured to an energy saving structure. The increasing rate of energy consumption dropped to 3.8% in the first half of 1980's because of the relatively high expansion of the less energy intensive industries such as the machinery and equipment industries. The share of energy demand of the energy intensive industries, however, still accounted for about 70% in the manufacturing industries which had their proportion of 91% in the total energy demand of the industrial structure, it is assumed that the less energy intensive industries will grow more rapidly than the energy intensive ones in the future. The share of the less energy intensive industries in GDP will increase from 25.6% today to 35.8% in 2010 and 38.9% in 2025. Among the energy intensive industries, the share of steel and cement industries in GDP toll decrease from 1.7% to 1.0% and 0.3% respectively. (Refer to Table 7).

The energy intensity in industrial sector is assumed to decline due to various factors such as the technological improvement, structural change, introduction of energy efficient manufacturing process and energy conservation efforts. Aggregate industrial energy intensity is assumed to decline to 37% of the value in 1985 by 2025 under the HE scenario and to 30 % under the LE scenario. It is assumed that the energy intensive industries will achieve the energy efficiency slightly higher than the less energy intensive industries will do. The energy intensity is projected to decline to 43% for energy intensive ones and to 46% for less energy intensive ones.

Total energy use in the industrial sector is projected to increase from 35,019 thousand TOE to 77,658 thousand TOE in 2010. (Refer to Table 11)

The structure of fuel mix in the sector is also expected to change significantly. The share of coal is projected to decline from 33% in 1985 to 20% under the HE scenario and to 16% under the LE scenario in 2025. On the other hand, natural gas and electricity will increase so rapidly that the share of these energy sources are projected to be 11% and 26% respectively under the LE scenario and 5% and 24% respectively under the HE scenario in 2025.

Transportation Sector

The energy demand in the transportation sector has been pushed up very rapidly in the last decade in Korea as the number of vehicles and traffic volume have increased rapidly. (Refer to Table 4)

During the period of 1975 to 1990, energy consumption in the sector increased at a rate of 13.1% per annum, and its share in the total final energy demand has risen from 9.5% in 1975 to 18.9% in 1990. Gasoline consumption increased from 3,747 thousand Bbl to 23,693 thousand Bbl during the same period, which is the highest average growth rate per annum, 13.1%.

However, the current level of ownership of vehicle in Korea is still relatively low among the countries of similar income level. The number of vehicles is expected to increase steadily in the future. The ownership of passenger cars is projected to be 210 per thousand persons in 2025 for the HE scenario and 170 even for the LE scenarios. Those numbers should be compared to the level, 11.2 in 1985. The stock of passenger cars will increase from less than 0.5 million in 1985 to more than 10 million in 2025 under the HE scenario. The stock of other types of vehicles are expected to increase gradually. The average distance traveled per vehicle will decline as the stock of vehicle increases.

It can be expected that the average mileage per gallon will increase through the improvement of technology. However, as income rises people will prefer larger and comfortable car, which would offset the improvement of gas-mileage. The fuel efficiency in terms of liter/Km is projected to be improved slightly from 0.10 now to 0.08 in 2025 under the HE scenario. (Refer to Table 10)

Total energy demand by transportation sector is projected to increase from 279 PJ in 1985 to 1917 and 1388 PJ in 2025 under the HE scenario and under LE scenario respectively.

Agricultural Sector

Agriculture sector was an important sector in Korean economy before the economic development. Since Korean economy has developed through industrialization, the sector has developed slower than the other sectors. Agriculture sector accounts for only 2% of total energy consumption. This share is expected to decline continuously to 1.5% in 2025. However, the energy demand will increase from 40 PJ in 1985 to 109 PJ in 2025.

Energy demand by Fuel Type

As the economy grows, the structure of energy demand by fuel type has changed over the last few decades. As shown in table 3, firewood was the major energy source at the beginning of the development. Since then, the massive coal development was initiated for the substitution of firewood resulting in coal becoming the major energy source in the Korean economy. However, in the 1970's, petroleum use has increased substantially because of the intensive investment to the heavy and chemical industries. The oil dependence in primary energy consumption reached its peak in 1978 with the share of 63.3%. With harsh experiences of two oil crises in 1970's, a great effort has been made to substitute oil with other energy resources like bituminous coal. The rate of oil dependence has continued to decline to 49.6% in 1989.

Nuclear energy, LNG, bituminous coal which had been rarely used until 1970's became the major energy sources in Korea after 1980's. Nuclear energy consumption increased greatly after 1983, accounted for 14.6% of the total energy demand in 1990, and bituminous coal and LNG accounted for 15.9% and 3.0% respectively. Demand for these energy sources is expected to increase steadily in the future. Nuclear energy was ambitiously introduced into power generation in Korea in the 1980's. As of the end of 1990, there are 8 reactors (7,615 MW) in operation in Korea. Nuclear power generation amounted to 47,365 GWH in 1989, representing 51.7% of total fuel consumption for generation in 1989. Demand for bituminous coal is also being increased especially in electricity sector. Oil-fired power plants are being substituted by coal-fired power plants. There is a plan to build 23 new bituminous coal-fired power plants in 20 years.

Coal market consists of two submarkets: anthracite and bituminous coal market. Although anthracite is still the major fuel for the residential and commercial sector, it is forecasted to be switched to more clean and comfortable energies as the income level rises. In fact, fuel switching has been actively occurring recently. However, bituminous coal consumption is expected to increase rapidly because the industrial sector makes efforts to substitute oil with bituminous coal and further there is a long term plan to build 23 new bituminous coal-fired power plants in 20 years. Therefore total coal consumption is expected to increase to 68.2 million tonnes in 2010. The share of coal in total energy demand will decline from 26.6% in 1990 to 21.2% in 2010.

Oil demand is expected to increase steadily inspite of the efforts to reduce the oil dependency. The share of oil in total energy consumption will be 55.9% in 2010. Demand for natural gas will increase rapidly as it will be a major substitute for anthracite coal in the residential and commercial sector on behalf of coal and oil. Thus natural gas will play the major role in the residential and commercial sector on behalf of coal and oil. The natural gas consumption will be 10.5 million tonnes in 2010, which will account for 6.6% of the total energy consumption.

With the current industrial structure and technology in Korea, it is hard to increase the share of renewable energy. The share of renewable energy will increase very slightly from 1.1% in 1990 to 1.6% in 2010.

Environmental concerns in Korea

As a result of rapid industrialization, the high population density, high urbanization progress, major cities and industrialized zones are now suffering from aggravating environmental problems like air pollution, water pollution and public nuisance caused by disposals of hazardous wastes. The issue of environmental protection has become one of the primary policy concerns in Korea.

As for global warming problems, CO_2 release is believed to have grave impacts on the problem. The major reason for CO_2 emission is the use of energies such as coal and oil. As the amount of such fuels is expected to increase steadily with the economic growth, the amount of CO_2 emission will reach 1.7 times the present level in the year 2000 and 2.2 times in the year 2010. (Refer to Table 15) The average growth rate of CO_2 emission will record 5.5% per year by the year 2000. Per capita CO_2 emission is also expected to increase at the average annual rate of 4.6% by the year 2000 after which the average increasing rate will slow down to 2.0% during the first decade of the next century.

However, it is expected that the CO_2 intensity with respect to energy consumption (CO_2/Energy) will not only decrease from 0.77 now to 0.75 but the CO_2 intensity with respect to GNP also will decrease from 0.50 to 0.33 in 2010. (Refer to Table 13)

CO_2 Emissions by Sector

The sectoral structure of CO_2 emissions will be changed. The electricity and transportation sector will outplace the other sectors including the residential and commercial sector in terms of CO_2 emissions.

The sector mainly responsible for CO_2 emissions in Korea is the industrial sector that accounts for 36.2% of the current CO_2 emissions, 23,422 thousand tonnes. The same sector is expected to remain the major sector of CO_2 emissions so that the CO_2 emissions from the sector will be 46,121 thousand tonnes and 65,236 thousand tonnes in 2010 and in 2030 respectively.

The transportation sector will grow the most rapidly as the number of vehicles are expected to increase rapidly. Even though only 18.4% of the total current CO_2 emissions are accounted for by the transportation sector, it is projected that this sector will emit CO_2 at about 34.3 million tonnes in 2010 which will be around 24.2% of total emissions. The CO_2 emissions from the residential and commercial sector will be stabilized at the current level, 18.0 million tonnes because the high CO_2 - emitting anthracite is being replaced by the relatively low CO_2 - emitting oil or gas.

There is a long-term plan to build 23 new bituminous coal-fired power plants in 20 years. The CO_2 emissions from the power plants will be about three times and six times as much as the current level, 9.8 million tonnes by the year 2000 and 2030 respectively. The share of CO_2 emissions in this sector will increase from 15.1% to 30.1% in 2030.

Comparing the CO_2 intensities with respect to energy consumption (CO_2/TOE) among the sectors, CO_2/TOE in residential and commercial sector is projected to drop drastically from 0.860 to 0.586 in 2010. CO_2/TOE in industrial sector will also decrease gradually from 0.669 to 0.594 in 2010. However, in transportation sector, it is hard to expect the decrease of CO_2/TOE because there is little room for fuel switching. CO_2/TOE is expected to be stable about the current level, 0.8. On the other hand, CO_2/TOE will increase in electricity sector because a number of bituminous coal-fired power plants will be in operation.

CO_2 Emissions by Fuel Type

Coal (including anthracite and bituminous coal) had been the major fuel emitting CO_2 in Korea by 1988. CO_2 emissions from anthracite will be reduced since anthracite consumption has been decreasing drastically after 1987. On the other hand, CO_2 emissions from the oil and bituminous coal will cause the doubling of the current level by the year 2000, since the expansion of power generation using these fuels is expected.

CO_2 emissions from using oil are about 33,950 thousand tonnes which will be forecasted to be 80,748 thousand tonnes in 2010 and to be three times as much as the current level in 2030. There is a trade-off in emissions from using coal. The CO_2 emissions from anthracite will decrease from 11,311 thousand tonnes to 891 thousand tonnes in 2010 while those from bituminous coal will increase from 16,921 to 47,892 thousand tonnes in 2010. The net effect of using coal will be the increase of CO_2 emissions from 28.2 million tonnes to 51.1 million tonnes in 2010. (Refer to Table 15)

Measures adopted to reduce emissions

The Korean government makes efforts to reduce GHG levels in many ways: reinforcement of energy conservation, improvement of oil refinery technology, preparation of environmental act etc.

In the energy sector plan, environmental protection objective was newly added in the 1988 revision of the sixth five-year economic development plan (1987-1991). More specifically, the energy policy measures and strategies for environmental objectives that have been implemented or announced by the government are: (1) Expansion of gas use in urban areas, (2) Raising the proportion of low-sulphur diesel and bunker-C and unleaded gasoline to 100.0 percent by 1991, (3) Strengthen environmental assessment studies for power plant construction and installing emission control devices to existing and newly constructed coal-fired power plants, (4) Enforcement of dust control in all coal briquette manufacturers, and reallocation of briquette plants outside of cities, (5) increasing government expenditure to 150 billion Won (equivalent to US$210 million) in next five years on R&D related to environmental issues.

Energy Conservation and Efficiency

Energy conservation affects directly the improvement of energy efficiency and indirectly the air pollution control.

Since the Five Year Economic Development Plan had been implemented in 1962, the industrialization required more energy demand and increased the overseas dependence rate. With a harsh experience of two oil crises and growing environmental concerns, energy conservation and efficiency improvements in all sectors are significantly considered in Korea. The government puts a great emphasis on the measures to improve energy efficiency. For example, in the residential and commercial sector, energy conservation effort has been strengthened by reinforcing the thermal insulation standards and regulations on constructing new houses as well as on commercial and public buildings.

However, there is an obstacle to improve energy conservation and efficiency. While the developed countries have much broader opportunities and much greater potential for energy conservation, the developing countries like Korea have little room to squeeze for energy saving because energy conservation opportunities and appliances are so meager. The speed of improvement of energy efficiency in Korea appears to be much slower than that of the developed countries.

The Energy intensity (Consumption/GNP) expressed in TOE/ 1000US $ at 1985 constant price has declined from 0.732 in 1980 to 0.595 in 1989. (Refer to Table 16)

Apart from the cross-wise comparison between developed and developing countries, a similar observation can be obtained from the changes of GNP elasticity of energy demand. Empirical analysis results obtained by using an econometric technique indicates that once the economy becomes more mature, energy demand growth would be significantly slackened relative to the economic growth, but demand pattern will be more responsive to price changes.

According to the empirical analysis, the GDP elasticity of total energy demand in Korea is shown to be 0.9853 in the 1970's, but to decline to 0.6894 in the 1980's, while price elasticity is shown to change from -0.0966 in the 1970's to -0.2743 in the 1980's. The decline of the GDP elasticity in the 1980's can be explained by energy conservation effort and the high expansion of the less energy intensive industries. On the other hand, more elastic response of energy demand to the price change in the 1980's implies that the effectiveness of pricing policy became more significant in the 1980's than the 1970's.

Preparation of Environmental Law

As pollution levels increased significantly during the 1970's, the Korean government enacted the Environmental Conservation Law (ECL) in 1977, and established the Office of Environment in 1980 in order to promote environment conservation more actively. A new article proclaiming people's environmental right was inserted in the National Constitution in 1980. The Office of Environment was upgraded to the Ministry of Environment in 1980, which is responsible for national environmental policy formulation and implementation of environmental protection activities. Under the Ministry of Environment, there are six Regional Environment Offices, the National Institute of Environment Research, the Korea Resources Recycling Corporation, and the Korean Environmental Management Corporation.

Special laws to deal with specific environmental issues were prepared under the ECL: Marine Pollution Control Law, Solid Waste Management Law, Toxic Substances Control Law, Air Pollution Control Law, Etc. In the Air Pollution Control Law, ambient air-quality standards were set for major air pollutants. (Refer to Table 16)

Table 1. Major Economic Indicators in Korea

	1971	1980	1981	1986	1988	1989	1990
GNP Growth Rate (%)	8.6	-3.7	7.4	9.8	12.7	6.7	9.0
Per Capita GNP (US$)	288	1589	1719	2298	4127	4968	

Source: "Yearbooks of Energy Statistics". Korea Ministry of Energy and Resources, 1991

Table 2. Major Energy Indicators in Korea

	1961	1971	1981	1986	1988	1989
Primary Energy Consumption (million TOE)	9.7	20.9	45.7	61.4	75.4	81.7
Per Capita Energy Consumption (TOE)	0.38	0.63	1.18	1.47	1.80	1.90
Energy/GDP Ratio (TOE/Million Won)	0.87	0.77	0.79	0.68	0.66	0.88
Elasticity (Energy/GDP)	-	0.65	0.61	0.73	0.98	1.37
Overseas Dependence	8.8	50.8	75.0	78.1	83.2	85.5
Rate (incld. nuclear)	(8.6)	(50.8)	(73.4)	(66.6)	(69.9)	(70.5)

ource: "Yearbooks of Energy Statistics". Korea Ministry of Energy and Resources, 1991

able 3. Primary Energy Consumption by Fuel

Unit : 1,000 TOE

ear	Total	Coal	Petroleum	LNG	Hydro	Nuclear	Fire Wood
965	12,012	5,238	1,455	-	178	-	5,142
970	19,678	5,829	9,293	-	305	-	4,251
975	27,533	8.075	15,637	-	421	-	3,420
980	43,911	13,199	26,830	-	496	869	2,517
985	56,296	22.022	27,142	-	915	4,186	2,031
990	93,193	24,387	50,175	3,023	1,590	13,222	797

ource: "Yearbooks of Energy Statistics". Korea Ministry of Energy and Resources, 1991

Table 4. Structure of Final Energy Consumption by Sector

Unit : %

Year	Final Energy Consumption (in 1,000 TOE)	Industry	Transportation	Residential & Commercial	Public & Others
1975	23,424	38.5	9.5	45.3	6.7
1978	32,418	40.4	13.6	40.2	5.8
1980	37,597	44.1	13.1	37.3	5.5
1985	46,699	42.8	14.4	38.3	4.5
1988	60,970	46.3	17.6	32.2	3.9
1989	65,804	46.9	18.6	30.4	4.0
1990	75,033	48.2	18.9	29.2	3.7

Source: "Yearbooks of Energy Statistics". Korea Ministry of Energy and Resources, 1991

Table 5. Energy Consumption in the Residential & Commercial Sector

change rate p.a.

	1976	1980	1985	1988	1989	77-85	86-89
Anthracite	64.1	61.8	62.1	57.1	49.0	5.4	-3.7
Fuel Oil	3.4	14.9	16.6	20.4	25.2	26.0	14.2
Gas	0.3	1.1	3.5	7.9	10.5	38.6	35.6
Firewood	29.3	17.9	11.3	5.9	5.2	-4.8	-15.6
Electricity	2.9	4.4	6.5	8.7	10.0	15.7	14.9
Total	100.0	100.0	100.0	100.0	100.0	5.8	2.4

Source: "Yearbooks of Energy Statistics". Korea Ministry of Energy and Resources, 1991

Table 6. E the Industrial Sector (%)

	.985	1988	1989	change rate p.a. 77-85	 86-89
Petroleum	3.5	51.8	51.6	3.0	10.5
Fuel Oil	4.5	34.5	35.7	0.5	12.4
Non-Fuel oil	0.0	17.3	15.0	10.8	6.7
Coal	2.4	33.0	33.2	19.0	12.1
Anthracite	0.8	1.0	0.7	-6.7	2.8
Bitu.coal	1.5	32.0	32.6	22.1	12.4
City Gas	0.1	0.4	0.5	-	80.2
Electricity	4.1	14.8	14.6	9.7	12.6
Total	0.0	100.0	100.0	7.1	11.4

Source: "Yea Statistics". Korea Ministry of Energ 1991

Table 7. Scena try Value Added Structure

Year	1985	2010	2025
Industry VA (Bi	38.82	259.27	490.94
Value Added Str			
Industry Total +	41.8	51.0	53.0
Manufacturing	30.3	40.0	42.0
Energy Inten	4.7	4.2	3.1
Steel	1.7	1.7	1.0
Cement	1.1	0.5	0.3
Chemicals	1.9	2.0	1.8
Non-Energy Inte	25.6	35.8	38.9
Mining, Const.,	11.5	11.0	11.0
Steel Output per	0.33	0.70	0.65
Cement Output per	0.57	0.85	1.00

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec. 1990

Table 8. Industrial Energy Intensity and its Change by Subsector

	1985	2010H	2010L	2025H	2025L
Energy Intensity (GJ/thousand US $)					
Industry Total	20.8	10.7	9.0	7.7	6.2
Manufacturing	26.9	12.8	10.8	9.1	7.4
Energy Intensive	97.9	54.7	47.7	41.9	36.0
Steel	139.6	79.8	71.5	69.8	63.3
Cement	98.2	65.5	57.9	54.2	50.3
Chemicals	59.5	30.8	24.8	24.8	18.9
Non-Energy Intensive	14.0	7.9	6.5	6.5	5.1
Mining, Const., Utilities	4.7	3.1	2.6	2.6	1.9
Energy Intensity (1985=100)					
Industrial Total	100	51	43	37	30
Manufacturing	100	47	40	34	27
Energy Intensive	100	56	49	43	37
Steel	100	57	51	50	45
Cement	100	67	59	55	51
Chemicals	100	52	42	42	32
Non-Energy Intensive	100	56	47	46	37
Mining, Const., Utilities	100	65	55	55	41

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec. 1990

Table 9. Forecasted Energy Mix in Industry Sector

	1985	2010H	2010L	2025H	2025L
Coal	33	39	35	30	15
Oil	52	46	45	50	46
Natural Gas	-	4	8	5	11
Biomass	-	-	-	-	1
Electricity	14	20	22	24	26

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec. 1990

Table 10. Scenario for the Transportation Sector

	1985	2010H	2010L	2025H	2025L
Value Added Structure (% of GDP)					
Transport	5.70	6.0	6.0	6.0	6.0
Road	4.08	4.0	4.0	3.7	3.7
Rail	0.36	0.3	0.3	0.2	0.2
Air	0.34	0.7	0.7	1.0	1.0
Ship	0.92	1.0	1.0	1.1	1.1
Per Capita Ownership (Vehicle per 1000 persons)					
Car	11.2	160	130	210	170
Taxi	2.4	8.0	7.0	11.0	9.0
Bus	10.5	48	40	60	50
Truck	3.1	18.5	16.0	25.0	20.0
Distance Traveled per Vehicle (1000 Km per Year)					
Car	20	14	15	13	14
Taxi	100	80	80	70	70
Bus	36	30	27	27	25
Truck	30	25	24	24	22

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec. 1990

Table 11. Forecasted Energy Consumption by Sector

Unit : thousand TOE

						Increasing Rate		
	1988	1990	2000	2010	2030	91-00	01-10	11-30
Industry	28,200	35,019	61,479	77,658	107,938	5.8	2.4	1.7
Trans.	10,747	14,757	32,729	42,828	51,860	8.3	2.7	1.0
Res. & Comm.	19,638	20,507	27,346	32,901	42,134	2.9	1.9	1.2
Public & etc.	2,385	2,934	4,607	6,148	8,999	4.6	2.9	1.9
Electricity	20,763	25,295	67,372	67,372	105,647	6.8	3.3	2.3
District Heating	26	24	1,855	1,855	3,912	45.2	6.4	3.8

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec 1990

Table 12. Forecasted Energy Consumption by Fuel Type

Unit : thousand TOE

						Increasing Rate		
	1988	1990	2000	2010	2030	91-00	01-10	11-30
Total	75.4	90.5	159.2	204.9	282.2	5.8	2.6	1.7
Petroleum	47.0	52.9	57.2	55.9	50.2	6.7	2.3	1.3
Natural Gas	3.6	3.0	6.4	6.6	7.4	14.2	2.9	2 2
Coal	33.4	26.6	22.1	21.2	21.5	2.0	1.0	1.5
Anthracite	16.5	10.7	3.3	1.3	0.3	-5.5	-6.3	-5.8
Bituminous	16.9	15.9	18.7	19.9	21.2	7.5	3.2	1.9
Hydro	1.2	1.7	0.6	0.5	0.4	-4.7	-0.5	1.1
Nuclear	13.3	14.6	12.8	14.1	16 3	4.5	3.6	2.3
Renewable	1.5	1.1	0.9	1.6	4.3	3.4	9.0	6.7

Source: "Long-Term Energy Demand Scenario and Carbon Dioxide Emission in Korea', Ji-Chul Ryu, Seung-Jin Kang, Dec. 1990

Table 13. Projected Major Indicators of CO_2 Emissions

	1988	1990	2000	2010	2030	average increasing rate 91-00	01-10	11-30
CO_2 (mil.ton)	57.6	64.7	110.3	141.9	193.1	5.5	2.6	1.6
Per Capita CO_2 (ton)	1.37	1.51	2.36	2.87	3.85	4.6	2.0	1.5
CO_2/GNP[2]	0.51	0.50	0.44	0.33	0.21	-1.3	-2.8	-2.2
CO_2/TOE	0.81	0.77	0.77	0.75	0.73	-0.1	-0.2	-0.1
GNP[3]	112.0	130.4	248.2	423.9	928.7	7.0	5.0	4.0
Popul.[4]	41975	42793	46828	49486	50193	0.9	0.6	0.1
Energy Demand[5]	75.4	90.5	159.2	204.9	282.2	5.8	2.6	1.6

1) Unit : % ; 2) Unit : ton/million Won at 1985 constant price
3) Unit : trillion Won at 1985 constant price
4) Unit : thousand ; 5) Unit : million TOE

Source: "Global Warming and Energy Policy in Korea", Korea Energy Economics Institute, Aug. 1991

Table 14. Projected CO_2 Emissions by Sector

Unit : Million ton

	1988	1990	2000	2010	2030	91-00	01-10	11-30
Industrial	19.7	23.4	35.9	46.1	65.3	4.4	2.5	1.8
Transport	8.6	11.9	26.3	34.3	41.3	8.3	2.7	0.9
Res/Commer.	18.5	17.6	18.1	19.3	21.4	0.3	0.6	0.5
Public/Etc.	1.6	2.0	2.9	3.7	5.0	3.7	2.4	1.6
Electricity	9.2	9.8	26.5	37.5	58.2	10.5	3.5	2.2
Dist. Heat	--	0.0	0.6	1.0	2.1	40.0	5.9	3.5
Total	57.6	64.7	110.3	141.9	193.1	5.5	2.6	1.0
Shares								
Industrial	34.14	36.19	32.57	32.50	33.79			
Transport	14.96	18.35	23.82	24.19	21.38			
Res/Commer.	32.19	27.26	16.41	13.60	11.09			
Public/Etc.	2.81	3.08	2.61	2.57	2.58			
Electricity	15.91	15.12	24.06	26.41	30.09			
Dist. Heat	0.00	0.03	0.53	0.73	1.07			

Source: "Global Warming and Energy Policy in Korea", Korea Energy Economics Institute, Aug. 1991

Table 15. Projected CO_2 Emissions by Fuel Type

						Increasing Rate		
	1988	1990	2000	2010	2030	91-00	01-10	11-30
Petroleum	25.4	34.0	62.0	80.7	102.4	6.2	2.7	1.2
Natural Gas	1.6	1.6	5.8	7.7	11.7	14.0	2.8	2.1
Coal	29.5	28.2	41.2	51.1	71.0	3.9	2.2	2.7
Anthracite	14.6	11.3	6.2	3.2	0.9	-5.8	-0.0	-6.1
Bituminous	14.9	16.9	35.0	47.9	70.1	7.5	3.2	1.9
Renewable	1.1	1.0	1.2	2.4	8.0	2.6	6.9	6.1
Total	57.6	64.7	110.3	141.9	193.1	5.5	2.6	1.6
Shares								
Petroleum	44.1	52.5	56.2	56.9	53.0			
Natural Gas	2.7	2.4	5.3	5.4	6.1			
Coal	51.3	43.6	37.4	36.0	36.8			
Anthracite	25.3	17.5	5.6	2.2	0.5			
Bituminous	25.9	26.2	31.7	33.8	36.3			
Renewable	1.9	1.5	1.1	1.7	4.1			

Source: "Global Warming and Energy Policy in Korea", Korea Energy Economics Institute, Aug. 1991

Table 16. Country Comparison of Energy Intensity

Unit : TOE/1000 U$

	1972	1980	1985	1988	1989
Korea	0.675	0.732	0.628	0.586	0.595
U.S.A.		0.632	0.531	0.490	0.487
Japan	0.409	0.328	0.281	0.266	0.264
Taiwan	0.595	0.519	0.446	0.434	0.428

Source: Calculated from Several Sources

Table 17. Air Quality Regulation in Korea

SO_2 Annual Average : below 0.05 ppm
24 hour Average : below 0.15 ppm
(should not be exceeded more than 3 times a year)
CO Monthly Average : below 8 ppm
8 hour Average : below 20 ppm
(should not be exceeded more than 3 times a year)
NO_x Annual Average : below 0.05 ppm
1 hour Average : below 0.15 ppm
(should not be exceeded more than 3 times a year)
TSP Annual Average : below 150 mg/m^3
24 hour Average : below 300 mg/m^3
(should not be exceeded more than 3 times a year)
O_3 Annual Average : below 0.02 ppm
1 hour Average : below 0.1 ppm
(should not be exceeded more than 3 times a year)
HC Annual Average : below 3 ppm
1 hour Average : below 10 ppm
(should not be exceeded more than 3 times a year)

CHAPTER 9 : THAILAND COUNTRY PAPER

Dr. Phol Sagetong
Energy Research Institute
Chulalongkorn University
Bangkok, Thailand

Executive Summary

Thailand's gross domestic product in 1989 has grown by 12.2% in real terms over the previous year, accompanied by a growth of 15.9% in final energy consumption. Of the total energy consumed in 1989, 47.2% was imported. This high level of imports, has led to a domestic policy which encourages use of domestic energy resources, which are natural gas, oil, lignite and biomass. Both firewood and hydropower (domestic resources) use are unlikely to grow, due to depleted forest reserves, the 'forest close down policy' and public opposition to construction of dams.

The use of fossil fuels like lignite and crude oil has been on the increase, hence strategies for limiting GHG's must concentrate on conservation, increased efficiency of production and utilization and increased usage of renewable energy resources.

A likely option is increasing energy utilisation efficiency in the transport sector which is a major consumer (38.9%) of the total energy consumed. Lowered energy consumption would limit GHG emissions as well as decrease energy imports. The CUERUI (Chulalongkorn University Energy Research Institute) has recommended measures like a mass transit system, maintenance of road surface among other measures. In the sector of power generation which is greatly dependent on fossil fuels (89%), co-generation could be considered a feasible option in the near future.

Development of renewable technologies has not received adequate attention from the government apart from the high cost involved. There is a limited use of such technologies in the rural areas.

As of the present Thailand has a 25-28 percent forest cover. The author has calculated a figure of 0.0345 million square kilometres of forest cover to balance CO_2 emissions from fossil fuel use.

The potential for maximum energy saving has been estimated, for the industrial, commercial, residential and public sector.

As far as CO_2 abatement technologies are concerned, two measures viz afforestation and energy generation from agricultural waste have been considered. At a cost ranging from 643.7 million to 748.8 million per year (based on a 5 year rotation) Thailand could save 11.9 million tonnes of carbon from being emitted per year.

A study conducted by CUERI and NEA on Electricity from rice husk as well as from agricultural waste indicates the existing potential in the rural areas to change from wood, charcoal or electricity use to electricity from agricultural waste based gasifiers. The cost of replacing all the electricity used by the industrial sector will be 640 million US \$, leading to a decrease of 1.103 million tonnes CO_2 per year.

Introduction

Thailand's gross domestic product in 1989 grew by 12.2% in real terms over the previous year. This was accompanied by a growth of 15.9% in final energy consumption. Table 1 shows some economic-energy indicators. Of the total energy consumed in 1989, 47.2% was imported. The use of fossil fuels is increasing every year, specially of lignite and crude oil, thereby making environmental problems more serious for Thailand.

Because of the high level of imports Thailand's energy policy emphasizes using domestic energy resources in order to reduce the country's burden on the balance of foreign payment. Thailand's domestic energy resources comprise natural gas, oil, lignite and biomass. Utilization of other domestic resources such as firewood and hydropower are unlikely to grow, due to the depleted forest reserves and the "forest close down" policy, as well as public opposition to construction of dams.

The NESDB and National Energy Policy Office (NEPO) are considering other alternative measures that can maintain economic growth while minimizing investment on the power plants. The major options recommended are

- emphasis on demand-side efficiency across all end-use and electricity sector;
- restructure electricity regulation for the industrial sector to generate its own electricity through

cogeneration and allow the sale of surplus electricity to the national grids.

Another strategy, besides energy conservation and waste fuel utilization, is to use domestic and imported natural gas as substitute fuel.

Table 2 gives the energy consumption, by type of fuel, for 1987, 1988 and 1989. The sectoral energy consumption for 1988 is shown in Table 3. The share of the transportation sector is highest at 38.90% of total energy consumption.

Future situation

Forecasts for energy consumption in the year 2000 and 2010 are shown in Table 4. It has been assumed that there are no significant changes in energy technology and utilization, and past trends continue upto 2010.

GHG emission

Carbon dioxide is emitted from two types of fuel

1/ From Fossil fuels : coal, oil, and natural gas

2/ From (Non) renewable fuel : fuel wood, charcoal.

To the extent that fuel wood and charcoal involve deforestation, it is non-renewable, and hence a net emitter of CO_2.

Table 5 shows the details of fuel consumption in 1989 by 5 different sectors. Each fuel is presented in physical units and is converted to tons of carbon. Table 6 gives the emission of carbon dioxide for 1989.

Table 7 shows the GHG emission in year 2000 and 2010 compared with 1989. The GHG emissions per capita increases from 2.78 tonnes in 1989 to 5.55 and 8.85 tonnes in year 2000 and 2010 respectively.

Table 6, shows that the emissions of carbon dioxide gas from fossil fuel (coal, oil, natural gas) equalled 25.8048 million tonnes of carbon, or 68% of total carbon emissions, (Non) renewable fuel, (fuel wood and charcoal) resulted in 11.949 million tonnes of carbon or 32% of total carbon emissions. GHG emissions projections for 2000 and 2010 is shown in table 7.

Thus, strategies for limiting GHG must concentrate on the fossil fuel utilization by way of conservation, increased efficiency of production and utilization, decreased utilization, or replacement with other sources of energy such as new or renewable energy resources, which are not net emitters of CO_2.

The utilization of (non)renewable fuel has to be stopped or replaced by wood from energy plantations. At the same time, there has to be a reduction in the rate of deforestation, and the ultimate aim should be to halt deforestation.

GHG limiting Technologies

There are three possibilities to limit GHG emission.

1. Improved utilization : which can be achieved by energy conservation and increased energy utilization efficiency. These will result in lower rates of emission and accumulation of CO_2 in the atmosphere.

2. Substitution of fuels : This can be done by stopping the use of fossil fuels, stopping deforestation, and using other clean energy sources or renewable energy.

3. Removal of GHGs from the atmosphere : The principle of this solution is to increase the retention of carbon in the form of solids and liquids. For example, fixing carbon in wood which is used as for construction material, or through shell-fish farming.

The following are some GHG limiting measures which may be applied to the present situation in Thailand.

Increase in Energy Utilization Efficiency

Industrial Sector

Table 2 shows that the industrial sector consumed 26.70% of total energy in 1988. Energy may be saved in this sector by adopting the following strategies :

1) **Heat Transfer Technology**

The small and medium scale industries are old and use low technology equipment based on obsolete design and small-scale operation. Energy losses occur in the plant at the energy production, energy transportation and utilization stages. These energy losses are due to inefficient fuel combustion, heat transfer to surroundings due to uninsulated piping, inefficient operation and design of equipment, as well as inefficient processes of production. Energy audits and analysis of two medium scale industries by TISTR. (Thailand Institute of Scientific and Technological

Research) show that at least 15-20% energy saving is possible through the improvement of boiler operation and system insulation.

Upgrading of technology or installation of new equipment in the production process will save energy, but this will be time consuming and capital intensive.

The attractive low price of lignite is causing industries to convert their boilers to use lignite as their main energy source. The consequence of this conversion will be the higher emission of CO_2 into the atmosphere. Lignite fuel pricing should be one of the alternative measures considered in order to control the greenhouse effect. In January 1990, NEA published a report entitled, "Electricity Saving Plan for the Industrial, Commercial and Residential Sectors". For each of these potential savings estimates, costs associated with each measure are assessed, and payback periods calculated.

2) **Electricity**

Electricity consumption in industrial factories was 4.82% of total energy consumption in 1988. The energy savings in this sector can be categorized into 4 major U52HA13Hsystems aQ rEported byOational Electricity Agency (NEA).

a) **Lighting System**

The installation of high efficiency lamps, reduction in number of lamps to an appropriate number and compensation with natural light are actions which may save 0.18% of the electricity consumption in the industrial sector.

b) **Cooling system**

Improvement of air conditioners and cooling system are possible by adopting various approaches such as, reduction of air leaks, control of temperature and condensate, installation of appropriate heating or cooling system, etc. These actions would save 0.7% of the electricity consumption in the industrial sector.

c) **Heating system**

Heating systems refer to machines and equipments in the production process which use electricity for heating. There are several approaches for improving heating systems, namely, improvement in efficiency of furnaces, insulation, etc. These measures may save 1.72% of the electricity consumption in the industrial sector.

d) **Other end - uses**

Apart from the systems mentioned earlier, existing machines and equipment can be improved through use of better air compressors, improvements in power factors, motor conveyers, etc. These actions could save 1.54% of electricity consumption in the industrial sector. The total electricity thus saved in the industrial sector is equal to 4.15% of electricity consumed by this sector or 0.2% of total energy consumption.

Transportation Sector

The transportation section accounted for 38.9% of total energy consumption in 1989, and the share of petroleum products in the same was nearly 100%. Saving energy in this sector will result not only in limiting GHGs emissions but will also decrease energy imports.

A study on Energy Consumption in Road Transport by CUERUI (Chulalongkorn University Energy Research Institute) showed that in a large city like Bangkok the average car speed was only 20 Km/hr in 1988 (in 1991 the speed was 12 Km/hr). Of the seven million cars in Thailand, 2 million are in urban areas. In the Bangkok area there are about 700,000 personal cars and 620,000 motorcycles, and only 26,000 buses.

The following policy measures were recommended by CUERI to the Government :

(1) A mass transit system of elevated electric cars is a necessity for passenger transportation in Bangkok. National plans for such a system should be accelerated in order to solve traffic congestion and reduce fuel consumption.

(2) A long term plan to increase traffic surface in Bangkok should be initiated.

(3) Existing traffic surface should be kept in good condition.

(4) Traffic lights should be efficiently utilized for traffic control.

(5) Freight transport on waterways should be encouraged and promoted as this would reduce freight traffic volume on roads.

(6) Freight transport on road should be made more efficient by using double trucks. This would reduce road surface requirements and increase efficiency of energy use in trucks.

(7) Tax measures should be initiated (after a mass transit system is in operation) to discourage the use of personal cars.

(8) Government should initiate and impose measures on car manufacturers to improve the efficiency of vehicles in order to save energy.

(9) Changes in oil price structure should be used to promote the use of gasoline and LPG, which are produced domestically, in road transportation.

(10) Extend the ring road around the city to promote higher traffic speeds and reduce commuting distances.

(11) Increase the number of cross-bridges for cars & trains at crossings in urban areas to reduce idling time.

(12) Oil or gas transportation by pipeline should be promoted.

The above measures can be implemented by the Government and require longterm planning with large investments.

Commercial, Residential and Public Sector

This sector consumed 30.40% of total energy in 1988. Recommendations made by NEA for energy savings in this sector are the following :

1) **Commercial buildings**

- Lighting system
  - (a) Replacement of ordinary lamps with high efficiency fluorescent lamps, and the use of compact fluorescent lamps instead of incandescent lamps in buildings.
  - (b) The use of key-switch controls in hotels when rooms are not occupied.
- Cooling system

  Control of operational efficiency in large buildings through the use of key-switch control should be undertaken. In small buildings, high efficiency air conditioners and the use of thermostats to control room temperature, proper design and insulation of air conditioned rooms and use of more efficient refrigerators should be encouraged to save energy.
- Heating systems

  In hotels or hospitals where hot water is used, air from cooling towers can be used to preheat water. This measure would save 5-10% of the energy consumption by this sector.

2) **Residential sector**

The energy consumption by this sector is very high. The energy used in this sector depends on economic growth or per capita income levels, as well as on social behaviour and life styles of the people. Energy savings are possible by adopting the following measures.

- Electricity

  Use of high efficiency lamps, high efficiency air conditioners, electronic thermostats for controlling room temperature, and installation of curtains. The International Institute of Energy Conservation reported that 50% savings are possible in this sector.

- Cooking system

  In future people are likely to shift from firewood to charcoal and then to LPG and electricity to meet the cooking energy demand. High efficiency stoves, high efficiency electrical kitchenwares, and high heating value of charcoal will help save energy. Total energy savings are estimated to be 10-20% (reported by NEA) in this sector.

Electricity generation

Nearly 89% of electricity generated is fossil-fuel based in Thailand. Fuel oil and diesel account for 9.8% of the electricity production (Table 8). All the fuel oil and diesel for power generation is imported.

Energy savings in this sector may be achieved by using cogenerating systems. Electricity generation from nuclear, hydro and solar sources in Thailand are not feasible option in the near future.

Development of Renewable Energy Technology

There have been many attempts to use renewable energy resources in Thailand, especially in rural area : Many prototypes of solar, wind, small hydro, geothermal stations are working now in a number of areas in Thailand (From NEA Report). Wide spread use of these renewable energy resources may take a long time due to lack of attention by the government in the past and the high investment cost of these technologies.

Thailand produces many agricultural products such as rice, cassava, sugarcane, maize, sorghum etc. Their production is well distributed all over the country and during all seasons. These principal agricultural crops have large agricultural residues such as husk, straw, bagasse, stem etc. Estimates by CUERI show that eleven agricultural wastes from seven principal agricultural crops have an annual energy content of approximately 28,000 Ktoe. The use of these energy sources in rural areas is possible but requires new technology.

Afforestation

At present, only 25-28% of the total area is under forests in Thailand. Deforestation for farming, charcoal making, fuel wood and for construction material continues despite government laws to arrest deforestation. The following methodologies have to be adopted to solve these problems.

Energy forest

People in rural areas use wood or charcoal as cooking fuel, therefore, the government will have to support or encourage farmers to plant fuelwood plantations for charcoal making and/or fire wood. The rate of plantation has to be sufficient to meet the energy demand for cooking. The area required for energy plantations to meeting cooking energy demand is 26,000 square kilometres, based on the assumptions of a five year life cycle of fuelwood, and 371 tons/km^2 yield of charcoal, as well as the use of high efficiency charcoal stoves designed by NEA.

Carbon-sink forest

Since major reductions in CO_2 emissions are not possible in the near term, it is important to retrieve as much CO_2 from atmosphere and fix it in a solid form such as wood or animal body (eg. shell fish). Plantation of fast growing trees for providing construction material, raw material for furniture industry are economic methods to balance the emission of CO_2 from fossil fuels use. Mangrove plantations are also very useful for providing a habitat for marine and shell fish living besides the seashore.

Thailand has a total area 0.512 million square kilometres. The land use pattern is shown in Figure 1. 25%

of the area is under forest, and 55% is agricultural land, it is possible to increase the percentage area under forests through increased efficiency in farming and accelerated afforestation and reforestation programmes.

By increasing land use efficiency we can reduce the farming area to 30%. In this way the land may be used for plantations, for balancing the CO_2 emission from biomass energy, and for retrieving CO_2 emitted by fossil fuels. To balance all the CO_2 emitted from fossil fuels in Thailand only 0.0345 million square kilometres of forest area are required.

The above method will help to stop or balance the carbon dioxide emissions, as well as decreasing the CO_2 from the atmosphere, if the rate of plantation is greater than the demand for firewood.

Estimated Energy Saved

From Table 2 and Section 4.1, the extent of energy savings from different sectors is summarized below.

Industrial Sector

- Energy saved is 25-35% of energy consumption by this sector or
- Energy saved is 7-8% of total energy consumption

Commercial, Residential and public sector

- Energy saved is 50% of energy consumption by this sector or
- Energy saved is 5.17% of total energy consumption

- Energy saved is 10-20% of renewable energy consumption

  or

- Energy saved is 2-4% of total energy consumption

Other Sectors

No energy savings are possible in sectors other than the industrial, commercial, residential and public sector without more advanced technology or large investments. Thus, potential for total energy savings is 16% of total energy consumption.

Table 9 shows the energy consumption for 2000 and 2010 based on this 16% saving in energy consumption.

Technology and cost for CO_2 abatement

Afforestation

Plantations have a low investment cost, do not require advanced technology, and therefore can be considered for achieving two objectives :

Plantation for energy purposes

Table 10 shows the returns to households and charcoal production from fast growing plantations. The total energy consumption from firewood and charcoal was 4806 KTOE in 1989. The area required for supplying this energy ranges from 0.089 million to 0.104 million depending on the scale of production. Costs range from 643.7 million to 748.8 million per year based on a 5 year rotation basis. Carbon dioxide emission of 11.9 million tonnes of carbon/year will be saved because there will be no CO_2 emissions from deforestation for energy purposes. The marginal cost of CO_2 abatement thus works out to between $54 and $62.9 per tonne of carbon.

Plantation for carbon - sink purpose

Table 6 shows that Thailand burned fossils fuels and released CO_2 equal to 25.8 million tonnes in 1989. This amount of carbon will accumulate in the atmosphere alongwith CO_2 emissions by other. To balance the carbon dioxide input and output into the atmosphere, retrieval of carbon as solids or liquids compounds may be a low cost option. Based on NEA's report on yield of plantations for a five year rotation, the total area required for fixing this amount of carbon is 0.0345 million square kilometres.

The cost of this plantation is assumed to be equal to the cost of plantation for fuel purposes. Total investment required would be 248.4 million US$ per year, but on maturity will yield saleable hard wood timber. New technology, ensures that the wood can be used both indoor and outdoor and be protected from insects. Wood of high strength and hardness can replace many plastics and cement materials. This will, additionally, result in the reduction of CO_2 emissions from cement factories and NO_x from burning of plastics.

Electricity and energy from agricultural waste

Table 11 shows the totAl energy92Hfromwaste residues of 7 principal crops for the year 1988. The total amount of energy yielded is 28.216 MTOE. This amount is greater than final energy consumption in the year 1989. Table 11 also shows that this energy is distributed over 3 regions of the country, namely, Northeastern, Northern and Central. The report of CUERI and NEA on Electricity from Rice Husk Gasifier and "Feasibility Study of Electricity Generation from Agricultural Waste" for rural area industries shows that many industries in rural areas can change from wood, charcoal or electricity use to gas or electricity from agricultural waste gasifiers. For example, the tobacco industry can use gas from biomass gasifiers instead of using lignite. Rice mills can use electricity produced from rice husk gasifiers, or burn gases from gasifiers to provide direct heat. There are nearly 30 rice mills and small industries in rural areas which use electricity produced by them using locally developed gasifiers (80-270 KW). The cost of installation of a 160 KW (or 1.2 million KW-hr or 102.24 TOE gasifier) is approximately 50,000 US$. Table 2 shows that electricity used in the industrial sector is 4.82% of total energy consumption or 1.105 MTOE/year.

To replace all the electricity used by the industrial sector, the cost of gasifiers will be 640 million US$. This will decrease carbon dioxide emission by 1.103 million tonnes/year. The marginal investment cost of abatement is thus, $38/tonne of CO_2 assuming a life of 15 years for the gasifier. If the government buys electricity from the private sector, the industries can operate the gasifier all through the year and sell the surplus electricity to the government. This will further reduce GHG emissions resulting from the combustion of fossil fuel such as lignite which are used as fuels for electricity generation.

Table 12, 13, 14 show the calculation of cost and benefits of the gasifiers for electricity generation.

Table 1 : Indicators of Economics and Energy

TYPE	Unit	1986	1987	1988
Population	Millions	52.969	53.873	54.961
GDP at 1972 Price	Million Baht	411,814	446,361	495,374
Change	%	4.5	8.4	11.0
GDP Per Capita	% Baht	7,774	8,285	9,013
Primary Energy Supply				
Total	Million TOE	27,994	30,536	32,702
Per Capita	TOE	0.529	0.567	0.595
Final Energy Consumption				
Total	Million TOE	19.556	21.048	22.929
Change	%	3.7	7.6	8.9
Per Capita	TOE	0.369	0.391	0.417
Per GDP (Energy Intensity)	KGOE/8	0.48	0.47	0.46

Table 2 : Final Energy Consumption 1987-1988

TYPE	1987		1988		1989	
	KGTOE	%	KGTOE	%	KGTOE	%
1 Modern Energy						
Coal or Lignite	674	3.20	808	3.50	1,082	4.07
Petroleum Products	11,223	53.51	12,687	55.60	15,001	56.45
Natural Gas	40	0 20	60	0.26	114	0.43
ElectricityWH2,121W52H10.08_&a3012HW,408				1U.50	2,98	10.53
Subtotal	14,058	66 99	15,963	70	18,995	71.48
'. Renewable Energy						
Fuel Wood	2,836	13 47	2,825	12 32	2,798	10.53
Charcoal	2,103	9 99	2,066	9 01	2,008	7.56
Paddy Husk	788	3.74	729	3.18	884	3.33
Bagasses	1,224	5 82	1,284	5.60	1,889	7.11
Subtotal	6,950	33.02	6,904	30.11	7,579	28.52
. Final Energy Consumption	21,048	100 00	22,927	100.00	26,574	100.00

Table 3 : Final Energy Consumption by Sectors 1988

		KTOE	%
1.	Agriculture	835	3.60
	Petroleum Product		99.40
2.	Industrial	6,111	26.70
	Modern Energy	3,807	16.63
	- Natural Gas		0.27
	- Petroleum Product		8.02
	- Electricity		4.82
	- Lignite		3.53
	Renewable Energy	2,304	10.07
	- Fire Wood		2.44
	- Rice Husk		2.02
	- Bagasse		
	5.61		
3.	Transportation	8,914	38.90
	- Petroleum Product		38.90
4.	Residential, Business, Commercial, Government	6,970	30.40
	Renewable Energy	4,600	20.06
	- Fire Wood		9.89
	- Charcoal		9.01
	- Rice Husk		1.16
	Modern Energy	2,370	10.34
	- Electricity		5.67
	- Petroleum Product		4.67
5.	Construction	98	0.40
	Total	22,928	100.00

Table 4 : Current Energy Consumption and Forecast for Year 2000 and 2010

TYPE	Unit	1986	1987	1988	2000	2010
Population	Million	52.969	53.873	54.961	69.704	84.969
GDP at 1972 Price	Million Baht	411,814	446,361	495,374	1,247,436	2,693,121
Change	%	4.5	8.4	11.0	8.0	8.0
GDP Per Capita	Baht	7,774	8,285	9,013	17,896	31,695
Primary Energy Supply						
Total	Million TOE	27.994	30.536	32.702	73,631	144.883
Change	%	3.7	7.6	8.9	8.9	8.9
Per Capita	TOE	0.369	0.391	0.417	0.915	1.761
Per GDP (Energy Intensity)	KGOE/B	0.047	0.047	0.046	0.051	0.056

Table 5 : Fuel Consumption in Year 1989

	1000 tons	mm lit.	mm scf	1,000 tons				kwh	1000 tons
Commodity transaction				Renewable energy					
	Lignite	Oil	Natural gas	Fuelwood	Charcoal	Paddyhusk	Bagasse	Electricity	Total amount
1. Agriculture	-	1903	-	-	-	-	-	90	
2. Industry	2270	2533	4725	141?	-	1812	1090	15431	
3. Transportation	-	12358	-	-	-	-	-	-	
4. Residential, commercial, etc.	-	1385	-	592?	2973	780	-	17313	
5. Power plant and others transformation	6780	1246	206674	1505?	-	910	-	1464	
Total amount	9050	19425	211399	2244?	2973	3502	10,0	34298	
Total amount (KTOE)	2763	16482	5194	8491	-	1194	119	1764	37782

Table 6

Fuel consumption and carbon emission in Year 1989

ommodity transaction	Lignite	Oil	Natural gas	Fuelwood	Charcoal	Paddyhusk	Bagasse	Electricity	Total
griculture	--	1,903 1,612	---	---	---	---	---	90	3,51
ndustry	2,270 1,574	2,533 2,146	4,725 70	1,473 626	---	1,812 489	10,590 4,051	15,431	8,93
ansportation	--	12,356 10,468	---	---	---	---	---	---	10,46
sidential, ommercial etc.	--	1,385 1,173	---	5,921 2,516	2,973 2,408	780 211	---	7,313	6,30
ower plant and ther transformation	6,780 4,702	1,246 1,055	206,674 3,069	15,055 6,398	---	910 246	---	1,464	15,47
otal amount (original nit)	9,050	19,425	211,399	22,449	2,973	3,502	10,590	34,299	---
otal amount	2,763	16,482	5,194	8,496	--	1,194	1,889	1,764	---
otal amount (000 tons)	9,050	19,425	4,218	22,449	2,973	3,502	10,590	---	---
% C Content	73.00	86.00	73.50	50.00	90.00	36.00	45.00	---	---
% Conversion Efficiency of carbon to oxide	95.00	98.50	99.00	85.00	90.00	75.00	85.00	---	---
otal carbon emission in tons of carbon x 10^3	6,276	16,455	3,139	9,541	2,408	0	0		37,81

Table 7 : Estimated CO_2 Emission year 2000, 2010

		Scenarios	
	1989	2000	2010
1. Population			
- Total (10^6)	55.888	69.490	84,708
- Growth rate (%)	2.000	2.000	2.000
2. GDP (1972 prices)			
- GDP 10^6 (Baht)	575,016	1,340,730	2,894,535
- GDP 10^6 US$	23,001	53,629	115,781
- Growth rate (% each year)	12.20	8.00	8.00
- Per capita (Baht)	10,289	19,294	34,171
- Per capita US$	412	772	1,367

3. Total Energy Supply			
- Total 10^6 (TOE)	37.782	93.851	182.356
- Per capita (TOE)	0.676	1.351	2.153
- Intensity (KOE/BAHT)	0.066	0.070	0.063
- Intensity (KOE/US$)	1.64	1.91	1.72
4. CO_2 Emission (in tonne of carbon)			
- Total (tonnes x 10^6)	37.77	93.92	182.49
- Per energy consumption (tonnes/TOE)	1.00	1.00	1.00
- Per capita (tonne carbon)	0.68	1.35	2.15

Table 8 : Source of Fuel for Electricity Production in Year 1988

Type	%
1. Natural Gas	57.7
2. Lignite	20.9
3. Hydro	11.6
4. Fuel Oil	9.7
5. Diesel	0.1

Table 9 : Estimated CO_2 Emission year 2000, 2010 Based on 16% Total Energy Saved

		Scenarios	
	1989	2000	2010
1. Population			
- Total (10^6)	55.888	69.490	84.708
- Growth rate (%)	2.000	2.000	2.000
2. GDP (1972 prices)			
- GDP 10^6 (Baht)	575,016	1,340,730	2,894,535
- GDP 10^6 US$	23,001	53,629	115,781
- Growth rate (% each year)	12.20	8.00	8.00
- Per capita (Baht)	10,289	19,294	34,171
- Per capita US$	412	772	1,367
3. Total Energy Supply			
- Total 10^6 (TOE)	37.782	74.330	160.473
- Per capita (TOE)	0.676	1.070	1.894
- Intensity (KOE/BAHT)	0.066	0.066	0.066
- Intensity (KOE/US$)	1.64	1.91	1.72
4. CO_2 emission (in tonne of carbon)			
- Total (tonnes x 10^6)	37.770	74.381	160.582
- Per energy consumption (tonnes/TOE)	1.00	1.00	1.00
- Per capita (tonnes)	0.68	1.07	1.90

Table 10 : Estimated yield from charcoal production

Scale	Plot size (ha)	Production of charcoal (ton)	Annual production cost (Baht/kg)	Revenue Baht	Internal rate of return
Household	2	6.30	1.55	10.600	15.0
Village	6	20.16	1.54	33.870	17.3
Cooperative	30	111.28	1.31	186.940	19.9
Business	75	277.19	1.20	467.000	21.7

Table 11

Total energy from waste residue of 7 principal agricultural products 2530/2531 (TOE)

Region	Rice	Sugar	Cassava	Maize	Soybean	Sorghum	Evea Rubber	Total
Northeastern	5,853,422.97	364,832.88	2,190,062.49	714,326.29	68,080.67	10,344.66	-	9,201,069.96
%	20.75	1.29	7.76	2.53	0.24	0.04		32.61
Northern	6,021,730.90	417,242.69	281,838.84	1,062,612.44	311,097.43	129,022.40	-	
%	17.80							
Central	1,179,836.19	1,665,561						
%	21.90							
Southern	1,121,792.44	-	-	-	-	-	505,373.54	1,627,165.98
%	3.98						1.79	5.77
Total	1,176,782.50	2,447,637.54	3,801,936.36	2,529,069.21	432,539.43	274,202.78	562,446.73	28,215,614.55
%	64.42	8.67	13.47	8.96	1.50	0.97	1.99	100.00

Table 12 : Project Feasibility Analysis - Scheme 1
Rice Husk Gasification for Rice Mills

Scheme 1a - Rice Husk Gasifier (160 KW x 2 units)
(US $ per rice mill)

Year	Cost	Benefit	Net Benefit	Feasibility Summary
0	67,059	69,176	(67,059)	IRR = 59.38%
1	26,235	69,176	42,941	NPV(6)= 213,827
2	26,235	69,176	42,941	NPV(10)=167,576
3	26,235	69,176	42,941	NPV(15)=125,056
4	26,235	69,176	42,941	
5	73,294	69,176	(4,118)	
6	26,235	69,176	42,941	
7	26,235	69,176	42,941	
8	26,235	69,176	42,941	
9	26,235	69,176	42,941	
10	26,235	69,176	42,941	

Scheme 1b - Rice Husk Gasifier (240 KW)

Year	Cost	Benefit	Net Benefit	Feasibility Summary
0	54,902		(54,902)	IRR = 46.26%
1	22,941	51,137	28,196	NPV(6)= 129,180
2	22,941	51,137	28,196	NPV(10)= 98,871
3	22,941	51,137	28,196	NPV(15)= 71,010
4	22,941	51,137	28,196	
5	54,314	51,137	(3,176)	
6	22,941	51,137	28,196	
7	22,941	51,137	28,196	
8	22,941	51,137	28,196	
9	22,941	51,137	28,196	

Notes: See Appendix 5.1 for more details
IRR - Internal Rate of Return
NPV - Net Present Value of the net benefits at 6%, 10%, and 15% discount rates

Table 13 : Economics of Scheme 1 - Rice Husk Gasification for Co-Generation

Case 1, two gasifiers with capacity 160 KW

Assumptions

Investment Cost	1.71 Million Baht
Husk Production	2640 Ton/yr.
Husk Use for gasifier	2096 Ton/yr.
Capacity of Rice Mill	50 Ton/day
Economic Use	10 Years
Interest Rate	15.00 %
Working Time	24 Hrs./Day
Husk Cost	0.10 Baht/Kg.
Electricity Buying Price	1.54 Baht/Unit
Plant Capacity	160 Kw.
Electricity Production	1840 1,000 Units/Yr.
Plant Electricity Consumption	120 1,000 Units/Yr.
Electricity Consumed For Rice Milling	360 1,000 Units/Yr.
Excess Electricity For Sale	1360 1,000 Units/Yr.
Electricity Selling Price	0.89 Baht/Unit

Labour	Unskilled	3,000	1	36,000	0.00% cost reduction
	Skilled	5,000	1	60,000	
	Shift work		3		
	Labour cost/yr		288		

Year	Invest.	Operation Costs		Labour	Total	Revenue	sales of	Total	Net
	Cost	Mainten.	Fuel		Cost	Saving	Elect.	Revenue	Benefit
0	67.06				67.06			0.00	(67.06)
1		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
2		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
3		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
4		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
5	47.06	6.71	8.22	11.29	73.28	21.74	47 43	69.17	(4.11)
6		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
7		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
8		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
9		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95
10		6.71	8.22	11.29	26.22	21.74	47.43	69.17	42.95